THE USE OF TIME SERIES ANALYSIS AS AN ANALYTICAL AND PREDICTIVE MODEL FOR SHARE PRICES ON THE JOHANNESBURG STOCK EXCHANGE

by

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INDEX

CHAPTER I

INTRODUCTION

The Johannesburg Stock Exchange (JSE) was founded in 1887 in a building in Simmonds Street. In 1903 it was moved to a new building in Hollard Street which served until 1960 when it was replaced. By 1979 when it moved to its latest premises, in Diagonal Street, the annual volume of shares traded exceeded 400,000,000, which had a traded value of more than R1,063m. The conditions within this market place are of vital interest to the investors who seek to participate in the major companies of this country. Of increasing interest to theorists and practitioners alike, has been the extent to which the "Efficient Market Theory" is applicable to the JSE.

Although the earliest work on the distribution of share prices was published at the turn of the century by Bachlier, it was not until the 1950's that papers by Roberts [1], Osborne [2] and Kendall [3]

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1) Roberts, H., "Stock market 'patterns' and financial analysis : Methodological suggestions", Jnl of Finance, March 1970, p.1-10 reprinted in Cootner, P.H. (ed), The random character of stock market prices, MIT press, 1964.

2) Osborne, M., "Brownian motion in the stock market", Operations Research, March-April 1959, p. 145-173, reprinted in Cootner, P.H. (ed), op.cit.

3) Kendall, M.G., "The analysis of economic time series Part I : Prices", Jnl of Royal Statistical Society, Vol. 96, Part I (1953), reprinted in Cootner P.H. (ed), op.cit.

ushered in a boom of research into this subject. Initial studies were directed towards the "Random Walk Hypothesis" whick postulates that share prices move randomly and that at a given point in time the size and direction of the next price change is random with respect to the stock of knowledge at that time. Subsequently the random walk came to be regarded as the "weak form" of the efficient market hypothesis. The semi-strong form asserts that prices fully reflect all publicly available information rather than just a knowledge of past share prices. The strong form arises when the qualification of "publicly" available information is removed.

Concurrently in the last two decades, the digital computer has become the common tool of analysists. Whereas many procedures, particularly in the field of numerical analysis, may have been so time consumming as to be prohibitive, they can now be carried out efficiently, in minimum time and at negligible cost. One of these methods is spectral analysis, which this study seeks to use to provide additional evidence on the validity of the weak form of the efficient market hypothesis, i.e. random walk.

In order to integrate the study, the following phases were introduced. Firstly, a definition of the various forms of random walk and efficient market theory is given so that the direction of the thrust of the empirical work can be clear.

Secondly, a literature review on the testing of the efficient market theory is given. In view of the volume of literature on this subject, it could not, within the limitations of this study, be regarded as exhaustive. Rather, the articles reviewed are intended to demonstrate the diversity of methods used, the opinions formulated and generally the large weight of evidence which supports the efficient market theory, except perhaps for the case of the strong form where few test results have been published to date.

Thirdly, the literature on tests of the share prices on the Johannesburg Stock Exchange, is reviewed. Here the evidence in support of the efficient market theory is less extensive. Indeed, recent debate has centered on whether the fact that a large number of the shares on the exchange are only occassionally traded, introduces non-randomness and/or inefficiencies to the market. Rather than pursue this particular aspect, this study attempts to fill the gap in another area, namely the longer term variations. In particular, other investigators have used weekly data with a tendency to go to daily figures, whereas this study uses monthly data.

Fourthly, a statement is made about the uses of spectral methods, particularly in the field of economics. Fifthly, in order that the reader is equipped to follow the analyses, a short development is given of the various functions used in spectral methods and the way in which they can be interpreted. It is not intended that this section should be mathematically rigorous, but merely provide heuristic insights.

Sixthly, the empirical methods are described, the results presented and conclusions drawn.

CHAPTER 2

EFFICIENT SHARE MARKET THEORY

2.1. GENERAL

In 1965, Fama[1)] published a paper which was to become the didactic work for the researchers, who, over the following decades were to rigorously debate the merits of the "Efficient Market Hypothesis". While particular attention has been paid to the New York Exchange and the behaviour of indeces in particular, work has also been published on the British, European, Australian and South African Exchanges. This chapter sets out to define the concepts of "Efficient Market" and "Random Walk" and to provide a basis for following chapters which review the empirical evidence that has been presented in support of the hypothesis. In particular, the role of spectral analysis will be highlighted.

2.2. EFFICIENT MARKET HYPOTHESIS AND RANDOM WALK

"A market in which prices 'fully reflect' available information is called efficient" [2)]. This, however, is so general a statement that it has no empirically testable implications and

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1) Fama, E.F., "The behaviour of stock market prices", Jnl of Business, Jan 1965, p. 34-105.

2) Fama, E.F., "Efficient capital markets : A review of theory and empirical work", Jnl of Finance, May 1970, p. 383

empirical work has thus been directed at the theory that market equilibrium can be expressed in terms of expected returns and that these are a function of the securities "risk".

Fama [3)] describes this notationally as:

$$E(\tilde{p}_{j,t+1} \mid \Phi_t) = \left[1 + E(\tilde{r}_{j,t+1} \mid \Phi_t)\right] p_{j,t}$$

where $\tilde{p}_{j,t}$ is price of security j at time t,

$r_{j,t+1}$ is the one period percentage return (earnings) and

Φ_t an operation depending on the information set and is in the sense that Φ_t is "fully reflected" in the price.

These assumptions have a major empirical implication in that they rule out the possibility of trading systems, based only on information in Φ_t, that have expected returns in excess of equilibrium expected profits. This also leads, in terms of game theory, to a "fair game" in which the excess of expected returns, based on Φ_t, is zero.

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3) Fama, E.F., <u>op.cit</u>, p. 384

There are two special cases of this model, viz.

1. The submartingale which has received little attention in the literature (A submartingale is a series in which the expected value, e.g. price, of the next period is equal to or greater than the value of the present period).

2. The Random Walk Model (Hypothesis) which has been the major direction taken by empirical studies and which is defined more extensively hereunder.

2.3. THE RANDOM WALK MODEL (RWM) - DEFINITIONS

Granger and Morgenstern [4)] define the random walk model as:-

> "If X_t is the (descrete) price series, the model suggested is that the first differences of this series appear to be purely random;
>
> in symbols $X_t - X_{t-1} = \mathcal{E}_t$
>
> where $\mathcal{E}_t$ has zero mean and is uncorrelated with $\mathcal{E}_{t-k}$
>
> all $k \neq 0$ "

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4) Granger, C.W.J., and Morgenstern, "Spectral analysis of stock market prices", Kyklos, Vol. 16, 1963(1), p. 2.

This is a special case, where $\alpha = 1$, of the Markov series of models

$$X_t - X_{t-1}\alpha = \mathcal{E}_t$$

Fama [5] states:

> "....... the theory of random walk says that the future path of the price level of a security is no more predictable than the path of a series of cumulated random numbers. In statistical terms the theory says that successive price changes are independant, identically distributed random variables".

Fama further points out that the theory of random walks actually involves two separate hypotheses, viz.

1. that successive price changes are independant and
2. the price changes conform to some probability distribution.

van Horne and Parker [6] express this as:-

> "Proponents of the random walk theory posit that the current market price of a given stock is independant

5) Fama, E.F., (1965), op. cit., p.34

6) van Horne, J.C. and Parker, G.G.C., "The random-walk theory : An empirical test", Financial Analysts Journal, Nov-Dec 1967, p87

of and unrelated to previous market-price patterns".

Levy,[7)] includes certain of the conditions and consequences as follows;

"The random walk hypothesis states that the stock market is not oligopolistic; but rather, that it is efficiently competitive, that there are enough well-informed analysts operating within a free market to result in instantaneous adjustment of price to value. If price does adjust instantaneously to value then successive security price change would be statistically independant".

Jones and Litzenburger [8)] also give an intuitive interpretation in defining random walk;

".....new information would be available to a large number of market participants ..... price adjustments would be instantaneously established by competitive interation .... stock prices would reflect intrinsic values".

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7) Levy, R.A., "Random walks : Reality or myth", Financial Analysts Jnl, Nov-Dec 1967, p. 69

8) Jones, C.P. and Litzenburger, R.H., "Quarterly earnings and intermediate stock price trends", Jnl of Finance, March 1970, p. 143

Kemp and Reid [9] distinguish between pure and mixed random walk models. The former contains the essence of the above definitions while the latter takes account of the differing actions of amateurs and experts in the market.

2.4. THE IMPLICATIONS OF THE RANDOM WALK MODEL (RWM)

If price changes are random as suggested by RWM than there is no link between the past and the future. This renders the work of the chartist or other statistical analysist largely spurious. Indeed the weight of empirical evidence to be described hereunder is such that the onus is on the analyst to prove that he can consistently use his techniques to make better than chance predictions of stock prices.

The fundamentalist also has problems, for, if the RWH applies, and the market is efficient, then it follows that share prices at any point in time will represent intrinsic or fundamentalist values. If, therefore, all investors are sharing information, further intrinsic analysis cannot be of any aid, since all such information is already included in the current share price.

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9) Kemp, A.G. and Reid, G.C., "The random Walk Hypothesis and the recent behaviour of equity prices in Britain", Economica, Feb. 1971, p. 29

"If the analyst has neither better insights nor new information, he may as well forget about fundamental analysis and choose securities by some random selection process". [10]

2.5. EFFICIENT MARKET FORMS

Fama [11] distinguishes the following test forms of market efficiency -

- Strong-form tests are tests which seek to establish whether certain individuals have monopolistic access to information and consequent higher expected trading profits or whether all available information is fully reflected in prices. An example of such monopolistic information has been reported by Niederhoffer and Osborne [12] who cite the example of specialists on the New York Stock Exchange.

- Semi-Strong form tests are concerned with whether current prices fully reflect all publicly available information.

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10) Fama, E.F. and Blume, M.E., "Filter rules and stock market trading", Jnl of Business, Security prices, a supplement, Jan 1966, p. 623.

11) Fama, E.F., (1970) op.cit. p.414

12) Niederhoffer, V. and Osborne, M.F.M., "Market making and reversal on the stock exchange", Jnl Am Statistical Assoc., December 1966, p.897-916.

Tests have been restricted to certain major types of information. Fama [13] reviews the published research on tests made after the announcement of stock splits, annual earnings, Federal Reserve discount rate changes and new issues.

- Weak form tests, test the Random Walk Hypothesis directly and are concerned with the statistical ability of historical data to predict the future. Where randomness is statistically proven, the Random Walk Hypothesis is established, however, to prove market efficiency it is necessary to show that "non-randomness" cannot be used to "beat the market". [14]

2.6. TESTING THE MODELS

This section largely follows the classification made by Gilbertson and Roux [15].

2.6.1. Statistical tests on price sequences.

These tests are directed at the independence or otherwise

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13) Fama, E,F., (1970) op. cit., p.497

14) Strebel, P.J., "The limited efficiency of the Johannesburg Stock Exchange", Investment Analysts Jnl., Aug 1977, p.15

15) Gilbertson, B.P. and Roux, F.J.P., "The Johannesburg Stock Exchange as an efficient market", Investment Analysts Journal, March 1977, p.21-27.

of successive price changes. The statistics of the sample set is compared to that which is expected under conditions of independence. As examples, the serial correlation of the set is drawn and is expected to be low under conditions of independence or the run test in which the length of runs is expected to be normally distributed [16]. A run is defined as a sequence of price changes of the same sign.

Gilbertson and Roux [17] review the criticisms of this form of testing as follows:-

- the independence of price changes refers to random walk and not necessarily to efficient markets.

- the non stationarity of the model for the efficient market, e.g. the submartingale in para. 2.2 above, will bias to rejection a test based on sample correlation coefficient.

- evidence suggests that the distributions are non-Gaussian and thus the variance for the infinite series

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16) Fama, E.F., (1965), op.cit., p.75

17) Gilbertson, B.P. and Roux, F.J.P., op.cit., p.23

does not exist finitely. The sample variance obviously does exist but must be interpreted with caution.

- the linear relationships implicit in the serial correlation model cannot identify the complex non-linear "patterns" sought by chartists.

2.6.2. Evaluation of Trading Rules

The most common trading rule is a so-called "filter" attributed to Alexander [18] -

> "An X% filter is defined as follows. If the daily closing price of a particular security moves up by at least X%, buy and hold the security until its price moves down at least X% from a subsequent high, at which time simultaneously sell and go short. The short position is maintained until the daily closing price rises to at least X% above the subsequent low at which time one should simultaneously cover and buy".

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18) Fama, E.F., (1965), op.cit., p.81

The test is based on a comparison between what the investor might have earned had he used the trading rule and what he would have earned using a buy-and-hold strategy. The interpretation is complicated by a need to prove consistency, the loss of interest on funds temporarily held in cash and the difference in expectations that the two strategies imply. [19)]

2.6.3. Portfolio Tests

Market efficiency implies that even the professional manager of a portfolio such as a unit trust will not consistently achieve performance superior to the market. The test for the efficient market hypothesis thus evaluates the performance of the portfolio (unit trusts in particular) against the market performance. Again the application of the test is limited by differences in ex ante expectations and ex post returns.

2.6.4. Distribution of successors to large values

Fama [20)] reports the testing of the hypothesis by

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19) Praetz, P.D., "Rates of return on filter tests". Jnl of Finance, March 1976, p.71-75

20) Fama, E.F., (1965), op.cit., p.85

Mandelbrot, that large changes may tend to be followed by further large changes, but of random sign, whereas small changes are followed by small changes. Statistically this infers that the conditional probability that the price change will be large, is higher than the unconditional probability (given that the immediately past change was high). The test compares the sample conditional distribution with the unconditional distribution.

2.6.5. Spectral Analysis

The test for Random Walk by Spectral Analysis falls into the category of "statistical tests". It attempts to use a more sophisticated model than for example, serial correlation, to prove random walk, by establishing that there is no statistical relationship between share prices, share price changes and various market parameters that would enable an investor to increase his performance above that of the market.

CHAPTER 3

LITERATURE REVIEW ON THE TESTING OF THE EFFICIENT MARKET AND RANDOM WALK HYPOTHESES

3.1. OUTLINE

It has been stated above that the paper by Fama [1] has become the didactic work for subsequent investigations of the efficient market and random walk hypotheses. It seems reasonable therefore to group preceeding work together and to review it chronologically. Thereafter the paper by Fama will be treated extensively before subsequent work is reviewed chronologically. A separate section will treat investigations of the Johannesburg Stock Exchange while the review of spectral methods in the wider economic sense will be delayed until the theoretical foundations have been laid in Chapter 4. It is noted here that the earlier work is largely reviewed from reprints in the book edited by Cootner [2].

3.2. EARLY WORK;

The paper by Bachlier,[3] published in 1900, is generally cited

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1) Fama, E.F., (1965), op.cit.

2) Cootner, P.H., (ed), The random character of stock market prices, MIT Press, 1964.

3) Bachlier, L., "Theory of Speculation", Am. Sci. Ecole Nom. Sup. (3) No. 1018, Paris 1900, as translated by Beness, A.J. and reprinted in Cootner, P.H., (ed), op.cit., p. 17

as the earliest work on random walk theory although the term is not used by him. The paper studies mathematically the static state of the market and seeks to establish the law of probability of price changes. "If the market, in effect, does not predict its fluctuations, it does assess them as being more or less likely, and this likelihood can be evaluated mathematically".

In 1953, Kendall[4)] attempted to establish whether the "so-called" trend in economic time series was in fact separable from the short term movements. He found that -

- where price series are observed at close intervals the random changes are so large as to swamp out any systematic effect. "The data behave almost like wandering series".

- small systematic effects are difficult to detect in these circumstances.

- model and trend fitting would be highly hazardous.

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4) Kendall, M., "The analysis of economic time-series - Part 1 : Prices", Jnl Royal Statistical Society, Vol. 96, Part 1 (1953), p. 11-25 as reprinted in Cootner, P.H. (ed), op.cit., p. 85

- aggregative index numbers behave more systematically than their components.

- there was little serial correlation within series or lag correlation between them.

Kendall's analysis was done on 22 series of weekly index prices - mostly shares but also including wheat and cotton prices. All the series were differenced before analysis. Kendall concludes that any cycles or trends which may be observed are "illusory" and that the best estimate of the change in price between periods is that there is no change.

Osborne [5] demonstrated that the price changes of common stock showed remarkable statistical similarity to the movement of particles in a random movement known as "Brownian Motion". Although separated by 50 years, the Bachlier and Osborne models are very similar. They both begin by assuming that the price changes between transactions are independant, identically distributed random variables with finite variance. These assumptions lead to the expected Gaussian distribution with the

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5) Osborne, M.F.M., "Brownian Motion in the Stock Market" Operations Research, March - April 1959, as reprinted in Cootner, P.H. (ed), op.cit. p.100-129

variance of the distributions proportional to the time interval chosen. Osborne also developes the proposition that it is not absolute price changes that are independant but rather changes in the logarithms of prices.

Although Osborne was the first researcher to consider individual share prices as opposed to indeces, his example is hypothetical.

Working [6] pointed out that the use of averages in series can introduce first order correlations that may not exist in the original series. In particular, he proves that where a monthly average is obtained by averaging the values at the end of the first and third weeks, the expected value of the first serial correlation coefficient is

$$E(r_1) = \pm 0,176$$

Working uses this result to explain the difference in behaviour between the wheat and cotton indices found by Kendall [7].

In 1960 Cowles [8] revised his findings of some 23 years previously,

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6) Working, H., "Note on the correlation of first differences of averages in a random chain", Econometrica, Oct 1960, as reprinted in Cootner, P.H. (ed), op.cit. p.129

7) Kendall, M., op.cit.

8) Cowles, A., "A revision of previous conclusions regarding stock price behaviour", Econometrica, Oct 1960, as reprinted in Cootner P.H.(ed), op.cit.p.132

which had been based on run analysis and which had found significant correlations in monthly averaged prices. He accepted the general proposition given by Working (see above) that where each unit of a time series is an average of points within that unit, the effect of such averaging will be to introduce positive first-order serial correlation in the first differences of such series even when the original series is random. After reworking most of his data he concludes:

> "A positive first-order serial correlation in the first differences has been disclosed for every stock price series (indices) analysed in which the intervals between successive observations are less than 4 years. When allowance is made for brokerage costs, however, there is nothing in this situation to indicate that the stock market is not functioning as a free competitive market".

Noting the work of Kendall on British prices, Moore[9)] used serial correlation and run tests on the Friday closing price of the Standard and Poors 500 index (hereafter SP500) over the period January 1942 to September 1958 to ascertain if the findings applied

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9) Moore, A;B., "Some characteristics of changes in common stock prices", in Cootner, P.H. (ed), op.cit. p.139

to the New York Stock Exchange (NYSE). He found slight positive serial dependance. He then extended his study to individual price relatives and found considerably higher serial correlation. He suggests that this is caused by large scale revisions in expected returns which occur from time to time but are spread over some time e.g. weeks or months. This will result in the "clustering" of positive and negative changes and an induction of serial correlation. This will be largely swamped in the case of indices.

Moore also seeks to explain the serial correlation by intuitively arguing for 5 independent variables and then performing a multiple regression to obtain the equation

$$Y = -0{,}09490 - 4{,}67X_1 + 0{,}00166X_2 - 0{,}00008X_3 - 0{,}00625X_4 + 0{,}00502X_5$$

The symbols used, in order of entry to the regression calculation, and the standard error of each coefficient (in parentheses) are

Y = share price	
X_5 = number of ex-dividend days	(5,140)
X_1 = $S_{\Delta \log p}$	(0,00098)
X_4 = total dividends paid	(0,00029)
X_2 = median price	(0,00278)
X_3 = number of Fridays not traded	(0,00195)

For this equation R^2 = 0,464, R = 0,681 and S_R = 0,114 and it thus explains a significant proportion of the variability of the serial correlation coefficients. Note that only X_4 and X_5 are large relative to their standard error.

Alexander in two papers [10] [11] has questioned the independence hypothesis. He observed that if stock prices really possessed independant increments, there could be no trading rule which would consistently produce a profit. Based on this idea, he formulated a "filter" rule and tested whether it would produce substantial profit above that of the market. In the first paper he used the Dow Jones and SP500 for the years 1897 through 1959. The tests claimed to show significant profits and Alexander decided that "speculative markets price changes appear to follow a random walk over time, but a move, once initiated tends to persist". An investor who applied such a filter rule could expect to earn excess profits.

In his 1964 paper, Alexander attempted to answer some of the critisms of his work which had been raised. Firstly, the choice of closing prices instead of weekly highs and lows could

10) Alexander, S.S., "Price movements in speculative markets : Trends or random walks", Industrial Management Review, May 1961, p. 7-26.

11) Alexander, S.S., "Price movements in speculative markets : Trends or random walks, No. 2" in Cootner, P.H. (ed), op. cit., p. 338

bias the model towards showing higher profitability for the filter rule compared to the non-discretionary trading. Secondly, because there had been no examination of the model generating the process, the theory lacked proof of consistancy. Finally, the results could be achieved if the process was non-stationary rather than non-linear.

Alexander produces results for a variety of filters ranging from 1% to 45,6%, as well as for Dow, Dazhi and Dafilt persistence formula. The tests are based on the 9562 daily closing prices of SP500 between 1928 and 1961. He takes account of transaction costs.

Alexander concludes:-

> "Taken together, the evidence runs strongly against the hypothesis that from 1928 to 1961 the movement of the SP500 is consistent with a random walk with drift".

Cootner [12)] postulates a market in which there are two substantial groups in the market. The "amateurs" have a high cost in obtaining

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12) Cootner, P.H., "Stock prices : Random vs. systematic changes", in Cootner, P.H. (ed), op. cit., p. 231

the information they need and tend to accept present prices as roughly representing true differences in value. They choose among stock on the basis of their own risk profile and on information which could just as probably be right as wrong. The other group is the "investors and speculators" who specialise in the market. As a result their search cost for information is low, although non-negative, and they have an idea of what is going to happen. They cannot, however, profit from it unless the current price deviates sufficiently from the expected price to cover opportunity costs. In this environment of amateurs and professionals, the path of stock prices over any substantial period of time would be composed of a random number of trends, each of which is a random walk with "reflecting barriers". There is much random behaviour in such a series but it is substantially different from random walk. The "barriers" imply that prices will move between upper and lower limits and be reflected from one to the other. The effect of the barriers would be to produce more small price changes than would be expected in a normal distribution with a large number of cases when the price was near the mean. This has inferences of leptokurtosis and stable paretian distributions.

To support his hypothesis, Cootner presents an analysis on a sample of 45 stocks on the NYSE. Weekly observations for five years over the period 1956 to 1960 were used. In the first part of the paper, a trading rule is tested and is found to show excess profits. This alone is evidence of either dependance or non-stationarity, although it is not evidence of market imperfections large enough to permit profitable mechanical trading rules.

Steiger [13)] points out that the results of Cootner and others are vulnerable to the claim that they lack statistical significance. Any series that has stochastic elements is likely to have unusual segments and the finding of non-random behaviour in a particular series such as the SP500 is not necessarily significant. This adds a dimension to the criticism of consistency noted against Alexander's results supra.

To establish a notion of significance Steiger utilises a sample distribution from a series generated by a pure random walk algorithm. This is compared to the run test results of a 14-company sample from the Cootner data. The conclusion is that the "results .... are rather strongly indicative of non-randomness in stock price movements". For the pure random series the distribution is clustered more about the smaller

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13) Steiger, W., "A test of non-randomness in stock price changes", in Cootner, P.H. (ed), op.cit. p.253

length sgements than for the share data which tends to the long end. This result supports the Cootner model of the random walk being modified by reflecting barriers.

Osborne [14] in a second paper pursued the comparison with Brownian particle motion but also examines a variety of aspects of trading, inter alia,

- differences in behaviour between high and low priced stocks
- distribution of trading volume
- "seasonality" of trading patterns and prices
- traders preference for certain prices.

Although all these effects result in statistically significant deviations from the random walk model, they do not deny the validity of the premise that the most probable value of the expected change in the logarithm of price of a random choice of share, at a random time, is zero. The results also show that where the deviations occur, they are so slight as to defy economic exploitation.

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14) Osborne, M.F.M., "Periodic structure in the Brownian motion of stock prices", Operations Research, May-June 1962, as reprinted in Cootner, P.H.(ed), op.cit., p.262

Osborne makes particular mention of the phenomena of resistance and support or in economic terms, the Taussig penumbra. This postulates that prices stay within a bounded range for an inordinate amount of time compared to a pure random walk. The "partially reflecting barriers" draw similarities with the Cootner model.

Mandelbrot [15] observed that the empirical distributions of price changes are usually too peaked to be relative to samples from Gaussian populations. He therefore, proposed that the Stable Paretian distribution be used and presented tests on cotton prices to illustrate this. Fama [16] points to the implications of Mandelbrot's Hypothesis, viz.

- the underlying economic conditions are subject to larger and more abrupt changes (and consequently share prices as well) than could be expected in a Gaussian distribution,
- the market is inherently more risky,
- speculators cannot protect themselves from large losses by means of devices such as "stop-loss" orders, since a large drop in prices will occur over

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15) Mandelbrot, B., "The variation of certain speculative prices", Journal of Business, Oct. 1963, p. 394-419

16) Fama, E.F., "Mandelbrot and the Stable Paretian Hypothesis", Jnl of Business, Oct. 1963, p. 420-429

fewer, larger steps and more rapidly than with a Gaussian market,

- the analysis is complex since variance is not finite.

3.3. THE WATERSHED - FAMA

The didactic work by Fama [17)] is divided into six sections which are reviewed hereunder in sequence.

In "Section 1 : Introduction", Fama states that the purpose of his paper is to review the theory underlying the random walk model and then to test the models empirical validity.

In "Section 11 : Theory of Random Walks in Stock Prices" the theory is divided into two hypotheses, viz. firstly, that successive price changes are independant and secondly that they conform to some probability distribution.

Statistically, independence means that the probability distribution for the price change in period, t, is independent of the sequence

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17) Fama, E.F., (1965), op.cit.

of price changes during previous periods. This is a theoretical ideal and is not achieved in sample series from empirical studies. More practically and related to the share market:

> "........ the independence assumption is an adequate description of reality as long as the actual degree of dependence in the series of price changes is not sufficient to allow the past history of the series to be used to predict the future in a way which makes expected profits greater than they would be under a naive buy-and-hold model" [18)]

In discussing the implications of independence, Fama points out that the use of devices such as charts are only effective in establishing independence but once this is done it has no economic consequences for the future. This is, however, not to say that the group of "superior intrinsic value analysts" cannot "beat the market", for, in a dynamic economy there will always be new information which causes intrinsic values to change. As a result, people who are both able to consistently anticipate new information and evaluate its effect on intrinsic values will usually make larger profits. Fama holds that in fact the

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18) Ibid, p.35

activities of these "superior" analysts is a major cause of independence. The implication for the average investor is that he is unable to consistently anticipate change in intrinsic worth ahead of the market and his investment decision will therefore be limited to his risk-to-return trade off, the classification of shares according to risk, and how risk categories combine in a portfolio. Since independence implies that the probable change in price for any share is zero, he may now select randomly from within any risk class.

In considering the probability distribution function of price changes, Fama reviews the Bachelier-Osborne model and the Mandelbrot hypothesis. The former implies Gaussian distribution with finite variance while the latter implies Stable Paretian with non-finite variance. It is noted that in the general random walk model, the type of distribution need not be specified. Any distribution with stationary or fixed parameters will be consistent with the theory as long as it correctly characterises the process generating the price changes.

In "Section III : A first look at the empirical distributions", Fama, describes the data used. These were the daily prices for each of the thirty stocks in the Dow-Jones index. The starting times of the share prices series used, varied between January, 1956 and April, 1958. All series ended on 26th September, 1972.

The tests were performed on the first difference of the natural logarithms, adjustments being made for ex-dividend days and for stock splits.

The empirical frequency distributions were compared to those of the Gaussian distribution and in all cases some degree of leptokurtosis was found. A comparison of the actual numbers of observations beyond 2,3,4 and 5 standard deviations from the means is compared to the expected numbers for the Gaussian distribution. Fama finds, for example, that whereas some 3 or 4 observations are expected to lie outside 3 standard deviations, the actual numbers ranged from 6 to 23. Probability graphing was also used to illustrate the deviations from normality.

One popular explanation for the deviation from normality is that the series consists of a number of sub-series. Fama tests the hypothesis that, in his tests which used trading days, a mixture of distributions would be produced by the fact that changes in price between the Friday close and Monday close actually involved three chronological days. The deviation from normality is found for both one-day and three-day distributions.

To test for non-stationarity, Fama divides the series into sub-series but finds the same characteristics as for the whole series. The behaviour of the distribution in the tails was found to be independant of the mean.

In "Section IV : A closer look at the empirical distributions", Fama tests whether the distributions of price changes have the crucial property of stability. This is proven through estimating the characteristic parameter α by means of double-log and probability curves, range analysis and sequential variance. The value is found to be consistently less than the value of 2 which would apply to a Gaussian distribution. It is concluded that taken together, the results of Sections III and IV support the Mandelbrot hypothesis.

In Section V : "Tests of dependence", Fama follows three main approaches, viz. serial correlation, run tests and performance tests of Alexander's filter trading rule. The difference between the statistician's approach in wishing to determine whether dependence is responsible for the long tails observed in the frequency distribution and the investors approach in wishing to establish any dependencies that may be used to increase his profits, is considered throughout the section. The three techniques have been reviewed in para. 2.5. supra and will not be further commented on here.

The results of the serial correlation and runs tests show little evidence of any dependence in the daily, four-day, nine-day and sixteen-day price changes. The dependence found was not strong enough to be used, either for increasing expected profits or to account for the departures from normality. Fama points out, however, that these analyses are not adequate tests of whether the past history of the series can be used to increase the investor's expected profits since they are neither sophisticated enough to pick up the complicated patterns sought by the chartist, nor able to identify changes of usable magnitude, nor do they test for dependence which may be present in only part of the series. Fama's preliminary results show that when using the Alexander filter, only 4 of the 30 share series showed greater profits than a naive buy-and-hold strategy. The comparison was based on the average obtained from a large number of filter sizes rather than on a specific size.

Fama tests the suggestion by Mandelbrot that one plausible form of dependence that could account for the long tails of the frequency distribution, is that large changes tend to be followed by large changes, but of random sign and finds that although there does seem to be more bunching of large values than would be predicted by a purely independant model, the tendency is not very strong.

In "Section VI : Conclusion", Fama affirms that his tests support the random walk model of share price behaviour.

3.4. POST FAMA (1965) TESTS OF EFFICIENT MARKETS

van Horne and Parker [19] recorded the daily closing prices for the period I January, 1960 to 30 June, 1966, of a random sample of 30 industrial shares on NYSE. The prices were then adjusted for stock splits and stock dividends and used to test trading rules. The rule tested was expressed as -

> "Buy a stock when its current price moves above a moving average of say X-days by an amount at least equal to a chosen threshold and sell when it falls below the moving average by an amount in excess of the threshold".

The paper presents results on a matrix of 30 rules, generated by using -

(a) 100, 150 and 200 day moving averages,

(b) 0,2,5,10 and 15% thresholds,

(c) short position allowed and not allowed.

The procedure allowed for earnings from short term investments

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19) van Horne, J.C. and Parker, G.G.C., "The random walk theory : An empirical test", Financial Analysts Jnl, Nov - Dec 1967, p. 87-92

when the investor was out of the market, re-investment of dividends, the allotment of dividends during short periods and the transaction costs. Initially it assumed that $ 10,000 was available for the purchase of each share and that only the original amount, plus earnings (including short term interest) were subsequently available for that particular share.

The principal finding of the study was the overwhelming superiority of the buy-and-hold strategy. The inability to profit from trading rules, even when transaction costs were ignored, supports the notion that there is not a meaningful degree of dependence in the series of price changes over time.

Levy,[20] "attempts to refute the random walk hypothesis - to support selected principles of technical analysis while maintaining standards of academic evidence". The data used was the weekly closing price of 200 shares on NYSE for 260 weeks between October, 1960 and October, 1965. The shares were chosen in the same industry representation as the SP500 and were a subset of the shares in the SP500, those mentioned in Moody's Handbook of Widely Held Stocks and those on NYSE.

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20) Levy, R.A., "Random walks : Reality or myth", Financial Analysts Jnl, Nov - Dec 1967, p. 69-77

All price series were adjusted for stock splits, share dividends and for the re-investment of both cash dividends and proceeds from the sale of rights.

The rule tested has been summarised by Jensen [21)] as -

> "In essence his (Levy's) rules consist of variations of the following:-
>
> (1) At the end of each week calculate the ratio of the securities current price to its average price over the previous 26 weeks (C/A26 ratio),
>
> (2) Rank the C/A26 ratios for all securities under consideration from high to low and invest an equal dollar amount in the X% of the securities having the highest values (or lowest rank),
>
> (3) Recalculate the C/A26 ratios and rerank all securities each week thereafter,
>
> (4) At each following week sell all securities currently held whose rank exceeds a certain "cast out rank" and

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21) Jensen, M.C., "Random walks : Reality or myth - Comment", Financial Analysts Journal, Nov - Dec 1967, p. 77-85

(5) immediately re-invest all proceeds from such sales equally in the X% of the securities currently having the highest values of the C/A26 ratio"

Similarly Levy calculates a C/A4 ratio and summates over the 200 shares to indicate the markets performance over the preceeding month.

Using a "relative strength" of 10% (i.e. X% in above) Levy finds that a "cast out" value of 160 yields the greatest return being 20,0% (after 2% round trip trading costs) compared to the 10,6% return available from a random strategy. The risk factors (variance) are also higher being 4,6% compared to 3,5%. Levy then demonstrates that the return can be further increased by using a 5% relative strength and yet further by introducing the volatility ranking of the shares as a second criteria. Volatility here is the coefficient of variation. Naturally risk is also increased.

In a third phase of testing Levy introduces criteria which reduce the risk of the portfolio. The purchase of bonds becomes an alternative. Levy claims to reduce the risk of the portfolio to that of the market, yet maintain the return at a value 45% above the market's geometric average.

Levy claims that the results invalidate the random walk hypothesis, both according to the Fama definition ("past history cannot be used to predict the future in any meaningful way") and the more precise Cootner definition ("except possibly for a trend, which is related to the desired rate of return, future changes in stock prices could just as well be determined by a flip of a coin as by any elaborate analysis of past data").

Jensen [22] has questioned the validity of Levy's results, regarding the returns as "overstated". His critism is based on four basic issues, viz.

(1) The "geometric average" as calculated by levy for the market comparison is naive. Inter alia, this is impractical as it involves the continuous re-distribution of the capital and earnings so as to maintain equal dollar investment in each share. In addition, Levy's evaluation of the market was in error and the figure of 10,4% should be 13,6%.

(2) After accepting that there is a risk difference between the portfolio selected by his analysis and the comparative strategy, Levy adjusts the risk downwards. Jensen

22) Jensen, M.C., op.cit.p.77-84

points out however, that he uses post-facto information to do so - an assumption not in keeping with a definition of risk based on the variability of expected returns.

(3) The methods ignore possible sampling error and selection bias.

(4) Levy assumes that the shares can be traded at the same values as used for the buy-sell decision. In particular the decision is based on the Friday closing price, whereas transactions must be made on Monday.

Jensen also points out that in terms of the capital asset pricing model if the market had been generally increasing in the 26 weeks Levy used to initially establish his portfolio, the selection would bias towards high beta and thus high risk shares.

van Horne and Parker [23)] in a subsequent paper changed their moving averages trading rule to one in which the most recent price changes were more heavily weighted than the older ones. They found that it was not possible to earn consistent excess profits with the weighted moving average decision rules tested.

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23) van Horne, J.C. and Parker, G.G.C., "Technical trading rules : a comment", Financial Analysts Journal, July - Aug 1968, p.128-132

Jones and Litzenberger [24] analyse the effect that quarterly earnings reports have on stock prices. They hypothesize that quarterly earnings reports significantly greater than those anticipated by market professionals from historic earnings trends, would cause gradual price adjustments over time as the change in belief of the market professionals concerning the fundamental value of a share is gradually disseminated to the general investing public. These changes would generate intermediate trends - a condition contrary to random walk theory and efficient market notions of the efficient and immediate distribution of information.

The data base consisted of the month-end prices for 510 companies between 1962 and 1965 and for 618 companies between 1964 and 1967. It was found that for 211 shares, where reported earnings exceeded the earnings trend line by more than 1,5 standard errors of estimate, the subsequent 6 month average price relatives for 139 of the shares were greater than the price relative of the SP500 index. The former was 17,5% while the latter was 5,3%. It is held that this discrepancy proves that the market does not adjust correctly and instantaneously for every item of information which becomes available.

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24) Jones, C.P. and Litzenberger, R.A., "Quarterly earnings reports and intermediate stock price trends", Jnl of Finance, March 1970, p. 143

Jensen and Berington [25] replicated Levy's tests on the "relative strength" or "portfolio upgrading" trading rule. Using 29 independant samples of 200 shares each, drawn from the university of Chicago's Monthly Price Relative file, they found that the trading rule did not consistently produce superior profits. The performance of the portfolio was evaluated in accordance with a model proposed by Jensen [26] where the measure of performance δ_j is given by

$$\delta_j = R_j - \left[R_F + (R_M + (R_M - R_F)/\beta_j\right]$$

where

R_j = rate of return on portfolio j

R_F = riskless rate of interest

R_M = rate of return on a market portfolio

β_j = systematic risk or volatility of portfolio j

The conclusion by Levy is not substantiated by the tests on the expanded sample and the trading rule returns are in fact slightly lower than a buy-and-hold strategy.

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25) Jensen, M.C. and Berington, G.A., "Random walks and technical theories : some additional evidence", Jnl of Finance, May 1970, p. 469-481

26) Jensen, M.C., "Risk, the pricing of capital assets and the evaluation of investment portfolios", Jnl of Business, April 1969, p. 167-247.

Fama [27)], in a 1970 review paper on efficient markets concludes:

> "The evidence in support of the efficient market model is extensive and (somewhat uniquely in economics) contradictory evidence is sparse. ..... Nevertheless ..... the old saw, "much remains to be done" ...... the most pressing field of future endeavour is the development and testing of models of market equilibrium under uncertainty".

3.5. RANDOM WALK ON EUROPEAN STOCK EXCHANGES

The results of Kendall have been reviewed in the section on earlier work in para. 3.2. supra.

Kemp and Reid [28)] analysed a sample of 52 daily closing prices of 51 shares and the Financial Times Industrial Index over the period from October 1968 to January 1969. The particular period of study was chosen to avoid both particularly "bullish" and "bearish" conditions and adjustments were made for "ex-dividend price falls, capitalization issues and the like". The tests used were firstly varieties of the runs test, viz. number of runs,

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27) Fama, E.F., "Efficient capital markets : a review of theory and empirical work", Jnl of Finance, May 1970, p. 383-417

28) Kemp, A.G. and Reid, G.C., "The random walk hypothesis and the recent behaviour of equity prices in Britain", Economica, Feb 1971, p. 28-51

Wallis-Moore test for cycles and runs up-and-down tests and secondly the Wald-Wolfowitz non-parametric test for auto-correlation.

They find that the random walk hypothesis has been "over-generalized" and that 50 per cent of the sample was significantly non-random, even after "no-change" situations had been removed from the data. From the auto-correlation tests they find several shares with significant negative auto-correlation. Their economic explanation includes the diffusion of information through an amateur-professional market environment a la Cootner and

> "Positive auto-correlation may be produced in the following manner. When a piece of information induces, say, a price rise X on day 1, the subsequent spread of the information on day 2 to a further group of potential buyers/sellers causes the price of the stock to rise further on that day. When there is negative auto-correlation, ..., a piece of information appearing on day 1 causes the price of share X to (say) rise. On day 2, when the information has spread further, there is a reaction to this higher price of sales (profit taking, normally) by the amateurs, causing prices to fall below that achieved on day 1".

Kemp and Reid conclude that their results should be a caution to those who have been startled by the "apparent finding" of randomness.

Notwithstanding their claim that the use of a large number of shares avoids the observance of isolated atypical behaviour, the 3 month selected period of the test cannot confidently be taken to apply generally. One of the main tenants required in this type of test is that of consistency.

Solnik [29)] has tested whether European share prices follow a random walk. The data base was 1310 daily prices over the period from March, 1966 to April, 1971 for 234 shares on 8 exchanges. Based on serial correlation tests, Solnik, finds that deviations from the random walk seem slightly more apparent than in the American case (a comparison with Fama's (1965) results). These deviations are, however, only about 4% and negligible from an investors point of view. It was further established that the serial correlation coefficients were fairly stable over time.

3.6. SHARE PRICES AND ECONOMIC INDICATORS

Hamburger and Kochin [30)] describe the ways in which monetary growth can effect stock prices.

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29) Solnik, B.H., "Note on the validity of the random walk for European stock prices", Jnl of Finance, Dec 1973 p. 1151-1159

30) Hamburger, M.J. and Kochin, L.A., "Money and stock prices : the channels of influence", Jnl of Finance, May 1972, p.231

The first of these effects is the "liquidity effect". The money held by wealthy holders is itself an asset and subject to the law of diminishing returns. Any increase in money supply decreases the benefits (utility) to holders and is thus a proxy for a decrease in the return on money. The reverse holds for a decrease in money supply. It is suggested that if institutions, dealers and wealthy individuals who hold the bulk of the floating supply of corporate shares are the most responsive to changes in their money balances, then the returns on corporate stock will be among the first and most strongly affected of the interest rates.

The second effect is the "earnings effect". Evidence suggests that changes in the money supply are important for determining the level of effective demand and corporate earnings are one of the most responsive elements of income to such changes.

The third effect is the "risk premium". This holds that where the money supply fluctuates, it introduces additional uncertainty and consequent risk. The investor will thus require an additional risk premium.

Whereas, the earlier writers Keran [31)] and Modigliani [32)] had argued that money has an indirect influence on share prices, acting mainly through its effect on the long-term bond rate and corporate earnings, Hamburger and Kochin postulate that there is ample support for the hypothesis that a change in money supply has an important short-run impact on the share market which is independant of the influence money has on interest rates or expected corporate earnings. Their statement is supported by a reworking of certain of Keran's data and by their own calculations. The technique in both cases is multivariate regression with the independant variable used at various time lags.
In conclusion, it is stated that it is unlikely that the results presented will be of any value in earning excess profits in the share market.

The intent of a paper by Cooper[33)] is to:-

> "provide a plausible framework for estimating the relationship between the money supply and stock

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31) Keran, M.W., "Expectations, money and the stock market", Review, Federal Reserve Bank of St. Louis, Jan 1971, p. 16-31 (not available to the author)

32) Modigliani, F., "Monetary policy and consumption : The linkages via interest rate and wealth effect in the FMP model", Consumer spending and monetary policy : The linkages", Federal Reserve Bank of Boston, 1972 (not available to the author)

33) Cooper, R.V.L., "Efficient capital markets and the quantity theory of money", Jnl of Finance, June 1974, p. 887-907

market returns and, therefore, to offer another test of the efficient market hypothesis".

Cooper combines the simple quantity theory of money (SQ in his notation) with the efficient market model (EM) into a model (SQ-EM), which is expressed mathematically as -

$$r_t^s = A(L)M_t^a + B(L)M_t^u + e_t$$

where

r_t^s = returns,

m_t^a = anticipated (forecast) money change,

m_t^u = unanticipated money change,

e_t = error term and

A(L),B(L) = polynomials in L such that $L^j X_t = X_{t-j}$

The data used was monthly observations on price and money changes for the period 1947 to 1970, i.e. a sample size of 276. The market return was determined from the SP500 and the money supply was the US Federal Reserve Bank figure for currency plus demand deposits (M1). Cross-spectral analysis was chosen for three reasons:

(1) The above models are not parametrically specified i.e. there is little a priori information about the

precise form of the polynomials in the above equation, and inter alia, the phase spectrum can be used (notwithstanding Hause's comments - see para. 5.7.4.) to detect lags or leads.

(2) The relationship between money and share prices was anticipated to vary across the frequencies. Time domain techniques (such as regression) average the effect among variables across all frequencies and do not provide an adequate means of estimating the model.

(3) It is anticipated that coherency between money and returns will be much larger for the low frequencies. Since the spectrum for share returns would be flat, a regression analysis may indicate little or no relation between money and returns, whereas, for example, at low frequencies they may be highly correlated.

The spectral analysis shows significant coherencies for the lower frequencies which was consistent with the higher correlation obtained from a regression on the annual results. From the phase diagram it is concluded that returns lead money changes for these lower frequencies by one to three months. This rejects the simple quantity theory after Sprinkel [34] which holds that money changes lead share prices. It supports the efficient market theory since the relationship cannot be used to make excess profits. The explanation is advanced that anticipated money supply changes are incorporated into current share returns.

Kraft and Kraft [35] used seasonally adjusted monthly data to test the hypothesis of causality between share prices and their determinants. Both the share prices and their percentage change were used against the money supply (M1), percentage change in money supply, Moody's AAA bond rate and the ratio of the bond rate to the US Government long-term rate. The technique used was to apply two "prewhitening" filters, either that proposed by Sims, i.e. $(1-0,75B)^2$ or one estimated by the authors to be (1-B)(1-B) (where B is the backward operator) and then to regress the variables using price and its determinants as both dependant and independant variables.

The results show that there is no significant causality from the

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34) Sprinkel, B.W., Money and Stock Prices, Irwin, 1964

35) Kraft, J. and Kraft, A., "Determinants of common stock prices : A time series analysis", Jnl of Finance, May 1977, p.417

determinants to either the level or percentage change in share prices, thus providing support for the efficient market hypothesis. Further results confirm those of Cooper that causality in fact runs in the other direction.

3.7. STUDIES OF THE JOHANNESBURG STOCK EXCHANGE (JSE)

Affleck-Graves and Money [36)] were the first writers to attempt to test the random walk theory on JSE prices. Their data was the weekly prices between April 1968 and September 1973 for each of fifty selected shares. The sample size ranged between 220 and 277. The test used was of the weak form and consisted of examining the auto-correlation estimates for a number of lags between 1 and 20 periods. The issue of covariance stationarity is avoided by stating that the conclusions drawn are subjective and are only meant to provide an indication of how the true auto-correlations might behave. The first differences of the logarithms of prices were used.

The results show that there were only 7 out of 50 auto-correlations greater than two standard deviations from zero for lags of 1 and 2 weeks. Under the nul hypothesis of zero auto-correlation, 95%

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36) Affleck-Graves and Money, A.H., "A note on the random walk model and South African share prices", SA Jnl of Economics, March 1975 p. 382-389

of values are expected to be within two standard deviations of zero when based on the assumption of Gaussian distribution. Only 18 out of 400 further auto-correlation tests of lags greater than 2 weeks were more than two standard deviations from zero. From an examination of the average values and the signs, it is concluded that the assumption of zero auto-correlation is generally valid for lags of one or two weeks as well as for all other lags.

On testing two-week and three-week intervals it is found that the auto-correlation decreases with increasing difference interval.

A comparison with the results of Fama[37)] and Solnik [38)] show that the lack of auto-correlation is perhaps even more marked on JSE than NYSE and European exchanges. The authors conclude that the results support the random walk hypothesis.

Blomkamp [39)] used linear regression techniques to establish the relationship between share prices and GNP and further to account for residual variation by introducing a factor for interest rates. The share price in the previous year was also added to the regression. The data used was the annual share price index between 1950 and 1970,

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37) Fama, E.F., (1965), op.cit.

38) Solnik, B.H., op.cit.

39) Blomkamp, P.J., "The behaviour of industrial share prices in relation to Gross National Product and interest rates in South Africa", Investment Analysts Journal, June 1975 p. 9-15.

the GNP and the interest rate on long term Government Stock. All data was obtained from the SA Reserve Bank Quarterly Bulletin.

Blomkamp finds that the error of projection for one year ahead is 16,7% when using the regression equation that included all three independant variables. He further regresses the percentage changes but finds that only the percentage change in share prices (p_s) regressed against the percentage change in interest rate (p_i) has significant correlation. He obtains the equation

$$p_s = 12{,}013 - 1{,}656\ p_i$$

and finds that when used as a predictor for the following four years, (taking the correct value for the base year each time), the maximum error is a remarkably low -5%. Blomkamp postulates that a similar relationship could be obtained for monthly, weekly or even daily data and, given a prediction of interest rates, could be used to predict movements in share prices.

Hadassin [40] has reported tests on the applicability of random walk to earnings and share prices on the JSE.

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40) Hadassin, I., "An investigation into the behaviour of earnings and share prices of South African listed companies", Investment Analysts Jnl, Aug 1976, p. 13-24

The share sample consisted of 30 shares which were chosen to represent the various market areas or "strata" in some "sense" i.e. it was not a statistically random sample. All companies were large and had a twenty year record of earnings available. Share price tests were performed on the differences of logarithms of daily closing prices between January, 1971 and December, 1973. The differencing intervals chosen were one-, four-, nine-, thirty-, sixty and ninety-day. The earnings data were one-, two-, three- and four-year differences with absolute values and not logarithms being used. The sample length was the twenty years between 1954 and 1973. After adjustments for stock-splits, but not dividends, the data was subjected to van Neumann serial correlation ratio and runs tests.

The author concludes from the correlation tests on prices that :

> "when considered individually a minority of companies did behave randomly, while the majority did not. When the sample as a whole is considered, it is evident that the behaviour of share price changes of this sample,was not consistent with the random walk hypothesis".

A similar conclusion is reached from the runs tests. The author does not present the results of the tests on the earnings but merely notes that the conclusion is the same. They finally conclude that the JSE is not an efficient market.

Gilbertson and Roux in contrast to Hadassin find the market to be efficient. The results, detailed in two unpublished reports [41, 42], are summarised in a published paper [43].

In the first report they attribute the non-random nature of share price changes reported on smaller markets to :-

(a) "thin" markets and discontinuous trading,

(b) a generally poor information disclosure process, and

(c) the existence of priviledged information channels (inside information).

The data used in the tests was the daily closing prices for 24 shares during the period February 1971 to February 1976. Equal numbers of gold mining, other mining and industrial shares were used. The testing procedures followed those of Fama and will not be reviewed further.

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41) Gilbertson, B.P. and Roux, F.J.P., "The behaviour of share prices on the Johannesburg Stock Exchange", Johannesburg Consolidated Investment Co., unpublished report F76/67, 1976

42) Gilbertson, B.P. and Roux, F.J.P., "Trading rule tests for shares quoted on the Johannesburg Stock Exchange", Johannesburg Consolidated Investment Co., unpublished report F76/80, December 1976.

43) Gilbertson, B.P. and Roux, F.J.P., "The Johannesburg Stock Exchange as an efficient market", Investment Analysts Jnl, March 1977, p. 21-27

The results of the distribution tests show that the JSE shares showed greater leptokurtosis than those of the NYSE and had a mean characteristic parameter, α, of between 1,5 and 1,9. Serial correlation and run tests show that the changes were not completely independant but that dependence was of such a magnitude as not to be useful in increasing trading profits.

In their second report Roux and Gilbertson test the effectiveness of four trading rules when applied to the JSE. The data used was as for the first report, although not all the rules were tested over the full 5 year period, mainly because of the need to establish a moving average. The transaction price was taken as the average of the closing price which generated the buy/sell decision and that of the following day. Transaction costs were accounted for, but no short selling was allowed.

To avoid critisism founded on the bias [44], which results from the time that the investor is out of the market, the wealth ratios, expressed as an increase relative to the initial value for each of the trading rules and the naive buy-and-hold strategy, are compared in three ways, viz.

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44) Praetz, P.D., "Rates of return on filter tests", Jnl of Finance, March 1976, p. 71-75.

(a) Unadjusted ratio,

(b) Adjusted ratio assuming that the investor can make short term investments when he is long in the market,

(c) Adjusted ratio which allows for the abovementioned bias by accounting for the difference in expected returns during long and short positions (the latter is not allowed in the study and an appropriate adjustment is make).

The results show that the trading rules consistently underperform the naive buy-and-hold strategy. The authors claim that this indicates that the non-randomness found in serial correlation and run tests is not of sufficient magnitude to permit exploitation and thus that their results provide "persuasive support for the view that the JSE is an efficient capital market".

In their paper, the authors also report on a series of portfolio tests [45)], modelled on those of Jensen. It was found that the funds earned 1,6% per annum less than they should have, given their level of systematic risk. The two assumptions made, however, must qualify this to some extent. These were that the funds have certain statutory investment requirements to comply with and that dividends for the funds and for the market, would balance and could thus be ignored.

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45) Gilbertson, B.P., "The performance of South African mutual funds", Johannesburg Consolidated Investment Co., Unpublished report F76/84 (not available to the writer).

Strebel [46] has taken the view that at most the efficient market hypothesis only applies to half of the listed shares, i.e. those with average annual trading volumes in excess of at least a quarter million. He accepts that to date no trading rule has been found that would refute the efficient market theory but argues that since these tests rely on a comparison and consequently on a market model, the tests only support the theory to the extent that the underlying market models are valid. He further notes that previous investigators have all found non-random behaviour from serial correlation and run-tests. Whereas other writers have accepted the results of portfolio tests as proof of efficiency, Strebel introduces other data aimed at demonstrating that low trading volumes distort the market, a fact that could imply that the capital asset pricing model was not applicable, rather than that the market was efficient. The data further suggests that the lower the trading activity, the greater the chance of non-random behaviour. Indeed, when the data for the runs test is modified so as to disregard zeros resulting from no trading intervals, the low volume shares exhibit "highly significant non-random behaviour". Another argument arising from low volume shares is that these tend to be tightly held and thus the competitive market assumption is negated.

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46) Strebel, P.J., "The limited efficiency of the Johannesburg Stock Exchange", Investment Analysts Jnl, Aug 1977, p. 15-20

In a reply to Strebel's paper, Gilbertson and Roux [47] restate their conclusion of efficiency and refute the "partial efficiency" concept. Firstly, they point out that Strebel's implied assumption that non-Gaussion distributions are necessarily random, is incorrect. Secondly, their own data had in fact allowed for "false" zeros on non-trading days. Thirdly, the raw data used in the tests referred to by Strebel had been taken from weekly prices given in the Financial Mail and that in the case of low trading volume shares, this was not necessarily a transaction price but might reflect a buy or a sell offer. Fourthly, they publish the results of applying one of their trading rules to the prices of 14 of the low volume shares mentioned by Strebel. The performance of this rule was, if anything, worse than when applied to the high volume shares, a fact that reinforces the original conclusions.

Fifthly, regarding the portfolio performance tests, and the applicability of the CAPM, the authors deny that beta values were variable but rather that the tests were unable to establish stationarity. They further refer to the work by Jensen as well as Modigliani and Poque, who observed similar problems on other markets. Thus -

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47) Gilbertson, B.P. and Roux, F.J.P., "Some further comments on the Johannesburg Stock Exchange as an efficient market", Investment Analysts Jnl, April 1978, p. 21-30.

"Until such time as we have reasonable evidence that the beta's of South African mutual funds have quite unusual characteristics that invalidate existing theory, it would be premature to reject established performance measurement procedures".

Sixthly, in reply to Strebel's apparant conclussion that the CAPM is not valid when it underlies the measurement of mutual fund performance, Gilbertson and Roux point to some of the difficulties of testing the CAPM empirically and hold that Strebel's tests are inconclusive, particularly since CAPM applies ex ante and not ex post. Rejection of CAPM is not justified. They conclude -

"Given the above, our overall conclusions are that Strebel has provided no evidence in support of his position and therefore has no justification for re-futing the efficient market concept. Consequently, the results that we reported previously stand unchall-enged and we have no choice but to persist in our view that the JSE is an efficient capital market".

CHAPTER 4

THE USES OF SPECTRAL ANALYSIS.

4.1. VARIOUS DISCIPLINES

Brillinger [1] has provided a list is disciplines in which spectral analysis has been used since 1894. These include:-

(a) Physics - spectoscopy, general relativity and the movement of celestial bodies

(b) Electrical Engineering - power in various frequency bands, signal detection in radar, communications

(c) Acoustics - descriptive statistic for sounds

(d) Geophysics - seismic signals, ocean waves

(e) Medicine - electrocardiograms, EEGs

(f) Economics - further described in para 4.3.

(g) Biology - circadian rhythm

4.2. METHODOLOGIES

Brillinger [2] further details the methods in which spectral analysis

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1) Brillinger, D.R., Time series : Data analysis and theory , Holt Reinhart and Winston, 1975, p. 11.

2) Ibid, p. 179

can be used.

4.2.1. A Descriptive Statistic

Given a series the spectrum presents a condensation of data which is often more elementary than the original series and may suggest the nature of the underlying generating processes to the experimenter.

4.2.2. Informal Testing and Discrimination

Since the spectrum of white noise (i.e. a random signal) is constant, it has been used as an informal test to establish whether a series is random. Similarly where the relationship between two series is believed to be a functional one, the aptness of fit can be tested by observing how flat the power spectrum of the residuals is. Significant magnitudes in any band will indicate poorness of fit at that frequency.

4.2.3. Estimation

Where a linear process is to be fitted to the data, a large number of parameters may be involved. Estimates may be made for these parameters by spectral analysis.

4.2.4. Search for Hidden periodicities

Often the underlying periodic components of a series may not be apparent in a time domain trace since it may be confused by trend or random components. In the frequency domain, peaks in the function will immediately be apparent and the accuracy with which this frequency may be estimated can be judged by the width of the band.

4.2.5. Smoothing and Prediction

The accurate measurement of power spectra is an important stage on the way to determining Kolmogorov-Wiener smoothing and predicting formulas.

4.3. SPECTRAL ANALYSIS IN ECONOMICS

In the foreward to the book by Granger, Morgenstern states:-

> "Considering the long time that economists have been occupied with time series, it is striking that the evolution of advanced notions and correspondingly sophisticated methods for their analysis has progressed as slowly as has been the case ...... The development of spectral analysis, of which this book gives one of the first comprehensive accounts and to which it makes

significant contributions is an event of great importance" 3).

The book contains examples of spectral analysis on a number of economic series, including a number of historic interest, such as the Beveridge Annual Wheat Price Series 1500 - 1869, the New York commercial paper rate, 1876 - 1914, Woolworth share prices 1946 - 1960, Pig-Iron production 1877 - 1958 and National Bureau business cycles. Studies reported include some 30 economic indicators. The examples given for cross spectral analysis are the New York call money rate against the commercial paper rate 1876 - 1914, the bank debits outside New York against an index of industrial production 1943 - 1961, factory employment against industrial production 1919 - 1958 and Dow Jones industrial index against industrial production 1919 - 1961. Some 26 studies in cross spectral analysis are reported. Each of these 26 series are analysed against the Federal Reserve Board Index of Industrial Production as the reference series.

The intention is to predict economic conditions (cycles) from the indicator. The two indicators used which are of interest to this study are Dow-Jones and SP500 indeces. The former is

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3) Granger, C.W.J. (in association with Hatanaka, M.), Spectral analysis of economic time series, Princeton University Press 1964, pi.

found to lead the reference series by 4 months in the frequency band ($\frac{1}{48}$ - $\frac{1}{24}$ cycles per month) where it has average coherency of 0,4. The latter shows no definite phase relationships although the coherency in the frequency band $\frac{1}{240}$ - $\frac{1}{80}$ cycles per month is 0,6.

Granger and Morgenstern [4] were the first to use spectral methods to analyse share prices.

The series analysed were the Security and Exchange Commission's (SEC) weekly price series (1946-1961), monthly price series for six US companies (1946-1960), weekly prices plus trading volume of two further stocks, SP500 monthly 1915-1961 and Dow Jones monthly 1915-1961.

In an appendix to the paper, the power spectra for each and the cross spectra between most of the series are described. The spectrum for the SEC index for periods longer than 12 months shows higher values than would have been expected from a random walk. The authors attribute this to the American business cycle of approximately 40 months. Most of the series show prominent annual and eight-month components with 3,4 and 6 month annual harmonies also visible in some.

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4) Granger, C.W.J. and Morgenstern, O., "Spectral analysis of New York stock market prices", Kyklos, Jan 1963, p. 1-25.

The cross spectra show many significant coherencies but in no case is there any indication of one series leading any other. It is noteworthy that the coherencies obtained from the cross spectral analysis between price and volume traded, were very low and that the phase tended to oscillate about π . This indicates that the movements in the number of shares sold is unconnected to the movements in price.

The authors conclude that the market follows the random walk and that there are no results which would permit excess profits to be earned.

Nerlove [5], uses spectral analysis to study the precise effects of seasonal adjustment procedures on the characteristics of seventy-five economic series of the United States, inter alia, employment, unemployment, labour force and various categories thereof. From a comparison of the spectra and cross spectra before and after the adjustment, he concludes that the adjustment procedures remove far more from the series than can be considered "seasonal" and that the corresponding relationship between the series is distorted during the adjustment procedure. Both of these defects impair the usefulness of the seasonally adjusted series as indicators of economic activity.

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5) Nerlove, M., "Spectral analysis of seasonal adjustment procedures" Econometrica, July 1964, p. 241-286.

Fand [6] has tested the basic assumptions of the 1953 decision of the US Federal Open Market Committee to confirn its open market operations to short-term securities. The policy assumed that short and long term interest rates move together and that the latter could be controlled by adjustments to the former. The spectral analysis showed that there were important differences in the periodicities, the short term being characterised by seasonal and cyclical components and that the series were relatively independent. Thus the basic tenents of the policy were in error.

Smith and Marcis [7], using spectral analysis deduced that there were systematic lead-lag relationships between short and long term interest rates. This finding is refuted by Pippenger [8] who critisises the use of detrending by linear regression and the lack of confidence limits. These shortcomings lead to a misinterpretation of the spectra and there are in fact no significant relationships.

More recently Brick and Thompson [9], using cross-correlograms

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6) Fand, D.I., "A time-series analysis of the "Bills only" theory of interest rates", Review of Economics and Statistics, Nov 1966, p. 361-371.

7) Smith, V.K. and Marcis, R.G., "A time series analysis of post accord interest rates", Jnl of Finance, June 1972, p.589-605.

8) Pippenger, J.E., "A time series analysis of post accord interest rates:Comment", Jnl of Finance, September 1974, p.1320-1325.

9) Brick, J.R. and Thompson, H.E., "Time series analysis of interest rates : Some additional evidence", Jnl of Finance, March 1978 p.93-103.

rather than spectra find that the bond market is efficient in that the individual series follow a random walk and there is no evidence of a meaningful and consistent relationship over time between short and long term interest rates.

Eatman and Sealy [10)] have studied the manipulation used by banks whereby increasing or decreasing earning assets, the commercial banking system can create or eliminate deposits, thus affecting the supply of both money and bank credit. Liability management and asset behaviour are closely related and an essential element of this process.

10) Eatman, J.L. and Sealy, C.W., "A spectral analysis of aggregate commercial bank liability management and its relationship to short-run earning asset behaviour", Jnl of Financial and Quantitative Analysis, Dec 1977, pp. 767-778.

CHAPTER 5

MATHEMATICAL FORMULATION FOR TIME SERIES ANALYSIS

5.1. OUTLINE

This chapter sets out to provide the intuitive and theoretical backgrounds to certain concepts necessary for the understanding of spectral and cross-spectral analysis. Most of this section follows Chatfield [1]. For a more rigorous mathematical treatment reference can be made to Brillinger [2].

5.2. STATIONARITY OF DESCRETE PROCESSES

Intuitively, stationarity implies that the mechanism which generates the series remains unchanged or constant, with time. This is not to say that the generated function may not be stochastic.

In general this dissertation will consider that a sufficient condition of stationarity exists if the series has a constant mean and fluctuates about the mean with constant variance and that the

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1) Chatfield, C., The analysis of time series : Theory and Practice, Chapman and Hall, 1975

2) Brillinger, D.R., Time series : Data analysis and theory, Holt Reinhart and Winston, 1975.

frequency distribution is constant [3]. More generally "An r vector-valued time series $X_t, t = 0, \pm 1$ ...... is called strictly stationary when the whole family of its finite dimensional distributions is invariant under a common translation of the time arguments or, when the joint distribution of $X_{(t_1+t)a_1}$, ..., $X_{(t_k+t)a_k}$ does not depend on t for $t, t_1 \ldots t_k = 0, \pm 1 \ldots$ and $a_1, \ldots\ldots a_k = 1, \ldots r, k = 1, 2 \ldots$" [4].

In the "wide-sense" or "second order stationarity", a stochastic process is stationary if

$E[X_t] = m$, where m is the mean and

$E[(X_t - m)(X_{t-\tau} - m)] = \gamma_t$ where γ_t is the autocovariance coefficient at lag τ, for all t [5].

The nature of economic time series is, however, such that they are not stationary and exhibit trend. In terms of spectral analysis in the frequency domain (see para. 5.4.) this would result in a concentration of "power" in the low frequency components. The phenomenon known as "leakage" will result in adjacent frequency bands showing larger values that is actually the case and the swamping of significant cyclic effects.[6]

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3) Kendall, M., Time series, Charles Griffin and Co., 1976

4) Brillinger, D.R., op.cit., p 22

5) Granger, C.W.J., (in association with Hatanaka, M.), Spectral analysis of economic time series, Princeton University, Press, 1964, p.18

6) C.W.J. Granger and Morgenstern, O., "Spectral analysis of New York stock market prices", Kyklos, Vol. 16, 1963(1), p. 7

The answer to this problem is the "pre-whitening" of the series to induce stationarity and to remove trend. Provided that the underlying structure of the series is not changing with time it has been demonstrated both theoretically and experimentally, that spectral analysis may be used with confidence [7]. The methods used to induce stationarity were differencing and logarithmic transformation. The formulas are given in para. 6.3.

5.3. TIME DOMAIN : AUTOCORRELATION

Where X_t is a time series observed in time at $t = \ldots\ldots -2, -1, 0, 1, 2 \ldots\ldots$ and from which the mean has been subtracted, the autocovariance of X_t (if it exists) is defined as [8] -

$$\gamma_{t,\tau} = E[X_t, X_{t+\tau}] \quad \text{for } \tau = 0, \pm 1, \pm 2 \ldots\ldots$$

It is to be noticed here that mathematical expectation is used and that the values of X_t is a set of observations and not values drawn at random from a probability distribution [9]. The observed time series, X_t, may be regarded as one example of the infinite set of time series which may have been observed of the time series, x_t.

7) Granger, C.W.J., op.cit., p.8

8) Nerlove, N., "Spectral analysis of seasonal adjustment procedures" Econometrica, July 1964, p. 242.

9) Kendall, M., Time Series, Charles Griffin and Co., 1976,p.69

This infinite set of time series is sometimes called the "ensemble". Every member of the ensemble is a possible "realisation"of the stochastic process [10]. This dissertation will suppress further distinction between the continuous process, x_t, and its discrete realisation X_t.

In general, γ, is a function of time, t, as well as of lag τ. However, if the conditions of stationarity apply then γ will be a function of the lag alone. The result may be normalized by dividing each by the variance γ_0 to obtain the autocorrelation.

$$\rho_\tau = \frac{\gamma_\tau}{\gamma_0}$$

Since τ can assume the values

= 1, 2 ....

the set of values ρ_τ as well as its graphic presentation is known as the correlograms of the series. Since the values are derived from a set of observations, the correlogram or autocovariance functions are estimates. The limits of the correlograms lie between +1 and -1. Since γ_τ and γ_0 are unknowns, they have to be estimated by using the observed values X_t of the series.

5.4. FREQUENCY DOMAIN : SPECTRAL DISTRIBUTION FUNCTIONS

The approach followed here is the heuristic one after Chatfield [11].

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10) Chatfield, op.cit., p.34

11) Chatfield, C., op.cit.

It is not intended to be mathematically rigorous. More rigorous treatments are to be found in Brillinger [12] and Anderson [13].

Where a series is dominated by a component at a known frequency, ω, it may be described as $X_t = R\cos(\omega t + \theta) + \varepsilon$,

where

ω is the frequency (radians per unit time),

θ is the phase angle lag,

R is the amplitude of the component and

ε is a random component.

Where more than one component is present there will be more than one frequency ω_j. More generally

$$X_t = \sum_{j=1}^{k} R_j \cos(\omega_j t + \theta_j) + Z_t$$

If R_j and θ_j are constants, then the series is not stationary since the expected value of the mean, m, changes with time.

With some reduction

$$X_t = \sum_{j=1}^{k} (a_j \cos\omega_j t + b_j \sin\omega_j t) + Z_t$$

where

$$a_j = R_j \cos\theta_j$$

$$b_j = -R_j \sin\theta_j$$

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12) Brillinger, D.R., op.cit., p.23

13) Anderson, T.W., The statistical analysis of time series, Wiley, 1971, p.380

and in intergral form as $k \rightarrow \infty$.

$$X_t = \int_0^{\pi} \cos t \, du(\omega) + \int_0^{\pi} \sin \omega t \, dv(\omega)$$

which is known as the spectral representation. Chatfield [14)] then uses this concept to introduce the Wiener-Khintchine theorem that says for any stationary stochastic process with autocovariance function γ_k there exists a monotonically non-decreasing function $F(\omega)$ called the spectral distribution function such that

$$\gamma_k = \int_0^{\pi} \cos \omega k \, dF(\omega)$$

This is called the spectral representation of the autocovariance function. The physical interpretation of $F(\omega)$ is that it is the contribution to the variance of the series which is accounted for by frequencies in the range 0 to ω. Because of the trigonometrical representation of the series, the variation in frequencies in the range 0 to π also describes all variation beyond π . It follows that

$$\gamma(0) = \sigma_x^2 = \int_0^{\pi} dF(\omega)$$

A further interpretation that can be placed on the spectral distribution function is that the increase in the function over an

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14) Chatfield, C., op.cit.p114

interval is the sum of the mean square amplitudes of the frequency components in that interval [15]. It is this fact that has led electrical engineers, in particular, to affix the adjective "power", for, in a sinusoidal input, the power is directly proportional to the squared amplitude of the oscillation. In the case of a time series, the variance may be regarded as the total power [16].

Nerlove [17] describes the spectrum as the graphical representation of the variance σ^2 as a function of frequency.

For a non-deterministic process, the spectral distribution function may be differentiated with respect to ω to obtain the (power) spectral density function or spectrum.

$$f(\omega) = \frac{dF(\omega)}{d\omega}$$

The spectrum is one of the analytical tools to be used in this study. It is important to realize that the total area under the spectrum (curve) is equal to the variance of the process and that the ordinate at each frequency represents the contribution to variance of components with that frequency.

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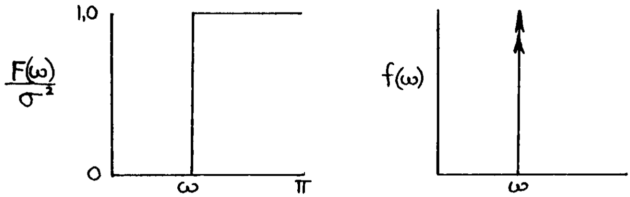
15) Anderson, T.W., op.cit. p.385

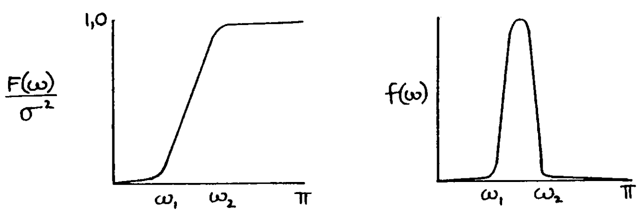
16) Chatfield, C., op.cit.,p.115

17) Nerlove, M., op.cit.,p.245

It is assumed here that the processes which we will study are not deterministic i.e., they cannot, for example, be described by a single sinusoid. Consideration of this situation, however, will help to explain the physical interpretation of the spectrum. Assuming that a deterministic component has a frequency ω, this will result in a step in the spectral distribution function and an infinite value for the spectrum at that frequency, i.e. graphically.

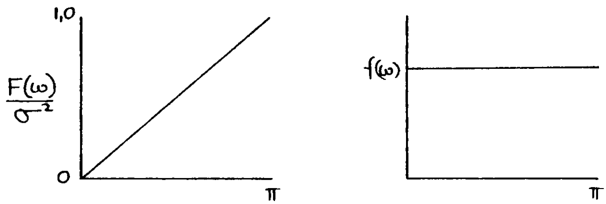


Where, however, the series can be described by, for example, a narrow band of frequencies and the spectral distribution is monotonically increasing, the large contribution by frequencies in this band will be shown by a spike in the spectrum, which unlike the above, has finite width i.e.



SPECTRAL DISTRIBUTION SPECTRUM

Where the contributions of all frequencies is the same, the spectral distribution function will increase linearly from 0 to π and the spectrum will be constant.



5.5. THE RELATIONSHIP BETWEEN FREQUENCY AND TIME REPRESENTATIONS

Both the autocovariance function and the spectrum are statistical representations of the series. The spectrum is the fourier transform of the autocovariance function which can be expressed as

$$f(\omega) = \frac{1}{\pi}\left[\gamma(0) + 2\sum_{k=1}^{\infty} \gamma(k)\cos\omega k\right]$$

Sometimes use is made of the normalised spectral density function by dividing by σ^2, in which case the normalised spectral density function $f^*(\omega)$ is the fourier transform of the autocorrelation function -

$$f^*(\omega) = f(\omega)/\sigma^2 = \frac{1}{\pi}\left[1 + 2\sum_{k=1}^{\infty} \rho(k)\cos\omega k\right]$$

5.6. CROSS SPECTRAL THEORY

The theory related to univariate spectra can be generalised to the bivariate case. In particular, a cross-covariance function is defined as [18)]

$$Cov(X_t, Y_{t+\tau}) = \gamma_{x,y}(\tau) = E\left[(X_t - m_X)(Y_{t+\tau} - m_y)\right]$$

which may be standardised to the cross-correlation function

$$\rho_{xy}(t) = \frac{\gamma_{xy}(\tau)}{\sqrt{\gamma_{xx}(0)\ \gamma_{yy}(0)}}$$

where γ_{xx} and γ_{yy} are the variances of X_t and Y_t and γ_{xy} is the covariance of X_t on Y_t. Where X_t and Y_t are series observed in time, the sample cross-correlation function, r_{xy}, is defined similarly except that sample variances are used.

For two uncorrelated series of white noise

$$E(r_{xy}(k)) \approx 0$$

$$Var(r_{xy}(k)) \approx \frac{1}{N}$$

18) Chatfield, C., op.cit.,p.170

where r_{xy} is the sample cross-correlation and N is the sample size. It follows that values outside the interval $\pm \frac{2}{\sqrt{N}}$ are significantly different from zero at the 5% level of significance.

By analogy with the univariate case, the cross-spectrum is defined as the Fourier transform of the cross-covariance function. However, because $\gamma_{xy}(k)$ is not an even function, $f_{xy}(\omega)$ is a complex function in the form [19],

$$f_{xy}(\omega) = c(\omega) - iq(\omega)$$

where the real part

$$c(\omega) = \text{co-spectrum}$$
$$= \frac{1}{\pi}\left\{\gamma_{xy}(0) + \sum_{k=1}^{\infty}\left[\gamma_{xy}(k) + \gamma_{yx}(k)\right]\cos\omega k\right\}$$

and the imaginary part

$$q(\omega) = \text{quadrature spectrum}$$
$$= \frac{1}{\pi}\left\{\sum_{k=1}^{\infty}\left[\gamma_{xy}(k) - \gamma_{yx}(k)\right]\sin wk\right\}$$

Further functions that can be defined are -

1. α_{xy} = cross-amplitude spectrum

$$= \sqrt{c^2(\omega) + q^2(\omega)}$$

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19) Chatfield, C., op.cit.,p.176

2. ϕ_{xy} = phase spectrum

$$= \tan^{-1}\left[-q(\omega)/c(\omega)\right]$$

3. $C(\omega)$= (squared) coherency

$$= \frac{c^2(\omega) + q^2(\omega)}{f_x(\omega) \cdot f_y(\omega)}$$

$$= \frac{\alpha_{xy}^2(\omega)}{f_x(\omega) \cdot f_y(\omega)}$$

4. $G_{xy}(\omega)$ = gain spectrum

$$= \sqrt{\frac{f_y(\omega)\ C(\omega)}{f_x(\omega)}}$$

$$= \frac{\alpha_{xy}(\omega)}{f_x(\omega)}$$

5.7. INTERPRETATION OF CROSS SPECTRA.

5.7.1. Co-Spectrum and Quadrature Spectrum

Twice the co-spectral density, $2c(\omega)d\omega$, gives the co-variance between the components that are "in phase".

Twice the quadrature spectral density, $2q(\omega)d\omega$ gives (to within a factor ±1) the covariance between the components that are in "quadrature" i.e. out of phase.

If $q(\omega) = 0$ and $c(\omega) \neq 0$, the components of the two processes are somewhat connected and are exactly in phase with each other.

If $q(\omega) \neq 0$ and $c(\omega) \neq 0$, then the two components will be both somewhat connected and somewhat out of phase [20].

5.7.2. Gain Spectrum

Gain can essentially be regarded as the regression coefficient of the process Y_t on X_t [21]. If Y_t is the result of a linear filter then a large gain would mean that the amplitude of that specific frequency is amplified. A small gain would mean that the amplitude is attenuated.

5.7.3. Coherency Spectrum

This function measures the linear correlation between the

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20) Granger, C.W.J.,op.cit.,p77

21) Kendall, M.,op.cit.,p.131

two components of the bivariate process at frequency ω and can be compared to the square of the usual correlation coefficient in that the closer it is to unity, the more closely the two processes are related at the frequency ω.

The coherency is the amplitude or sum of squares of the cross-spectrum, standardised by division by the separate spectral densities and surports to measure the degree to which the series vary together [22].

5.7.4. Phase Spectrum

The phase spectrum measures the extent to which the processes are in step.

Since the phase and coherency are related, it is necessary to consider the effect of fluctuations in the coherency diagram on the phase [23]. If the coherency is small at frequency ω, then both $c(\omega)$ and $q(\omega)$ will be small and so the estimate of $q(\omega)/c(\omega)$ is likely to have very large variance. Thus, in interpreting the phase diagram

22) Kendall, M.,op.cit.,p.131.

23) Granger, C.W.J.,op.cit.,p.89

only those points with significant coherency should be considered.

The interpretation of the phase ϕ in economic series has been used for example by Gargill to test the hypothesis that wages lag price changes. He uses phase as "the angular measure of the shift on the time axis of one series relative to another series which maximises coherence at that frequency" [24]. The shift expressed in the time units of the series can be obtained by

$$\text{tau} = \frac{\phi}{2 \pi \omega_o}$$

This interpretation was refuted by Hause [25], who judges as incorrect the belief that it is generally possible to infer lead-lag relationships by a simple transformation of the phase from cross-spectral estimates. The interpretation depends critically on the model that one assumes governs the relationship between a pair of time series. In particular tau is only meaningfull when interpreting time-domain relationships when the input and output of

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24) Gargill, T.F., "An empirical investigation of the Wage-Lag Hypothesis", The American Economic Review, Dec 1969, p.807

25) Hause, J.C., "Spectral analysis and the detection of lead-lag relations", The American Economic Review, March 1971, pp.213-217

linear systems are related by "pure delay" i.e. by processes of the form -

$$Y_t = \alpha X_{t-d} + \varepsilon \quad \text{where d is a time shift or delay}$$

and which infers that tau is independant of frequency. Indeed, Granger [26)] has suggested that there is no a priori reason why we should suspect such simple one parameter lead-lag relationships.

Subsequently, Hilliard and Barksdale [27)] reviewed the concepts of phase, tau and process models and concluded that the restriction of the tau interpretation to pure delay is unnecessarily conservative. It is necessary to differentiate between the uses of phase analysis as a means for suggesting plausible time-domain models and as a means of establishing timing relationships at specific frequencies. The interpretation of tau as the time delay at a specific frequency should not lead to erroneous conclusions.

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26) Granger, C.W.J.,op.cit.p.216

27) Hilliard, J.E., and Barksdale, H.C., "The time domain implications of phase angles and tau", Management Science, July 1976, p.1273

5.8. LOGARITHMIC TRANSFORMATION

The characteristics of many series, particularly in economics, are such as to render them difficult to analyse by spectral methods without an amount of conditioning. Granger [28)] states that for economic series, the logarithmic transformation is the most significant, i.e.

$$Y_t = \log_e X_t$$

If the mean is much larger than the standard deviation of the original series, the shape of the spectrum will be little changed by a logarithmic transformation.

The successive estimates of the cross-covariance function are themselves autocorrelated and the variance of the estimates depends on the auto-correlation of the two components. Thus, it is possible for series which are actually uncorrelated to give rise to large and spurious cross-correlation coefficients. To avoid this, both series should be filtered to convert them to white noise [29)]. This is effectively done through differencing.

Kemp and Reid [30)] give the reasons for the assumption of the

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28) Granger, C.W.J., Spectral Analysis of Economic Time Series, Princeton University Press 1964,p.47

29) Chatfield, C.,op.cit.,p.173

30) Kemp, A.G., and Reid, G.C., "The Random Walk Hypothesis and the recent behaviour of equity prices in Britain", Economica, February 1971, p.28-51

logarithmic transformation. Firstly, prices are bounded from below and unbounded from above. Secondly, the Weber-Fechner "law" of psychology applies, which postulates that while levels of sensation are not measureable, changes in level are. Thirdly, market operators are interested in proportional changes and not simply their absolute value.

The alternative assumption to the log transformation is based on the Mandelbrot hypothesis [31)] which holds that the stable Paretian distribution should be used to test for random walk. The findings of Fama [32)] supports this and Roux and Gilbertson [33)] have found this distribution to apply to the Johannesburg Stock Exchange. The most salient points are that although the price changes are symetrically distributed, there are abnormally large numbers of price changes near the distribution mode and in the tails (lepto-kurtosis) and further that the distributions are unvariant under addition. In this dissertation it is assumed that the differencing and taking of logarithms removes sufficient of the effects of trend to make the spectral analysis meaningful. It must be noted that the calculation of confidence limits also makes assumptions of Gaussian distribution.

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31) Mandelbrot, B., "The variation of certain speculative prices" Journal of Business, Vol. 36 (1963), p.394.

32) Fama, E.F., (1965), op.cit.

33) Roux, F.J.P. and Gilbertson, B., "The behaviour of share prices on the Johannesburg Stock Exchange", Unpublished report of Johannesburg Consolidated Investment Company, Report No.F76/67, p.3.

CHAPTER 6

DATA OF EMPIRICAL STUDY

6.1. SHARE DATA

Data for 11 individual shares was obtained from the data bank of the Bureau for Financial Analysis at Pretoria University (BFA). The period covered was 1970-1977, i.e. 96 months and adjustments have been made by the BFA for stock splits, capital issues, rights and reverse stock splits. The raw data is kept on a monthly basis and the specific parameters used were

- volume of shares traded,
- dividends declared and
- value of shares traded.

The average price during the month was obtained by dividing the value of the shares traded by the volume of shares traded. The earnings were calculated as

$$E_t = \frac{P_{t+1} - P_t + D_t}{P_t}$$

where E_t = earnings in period t,

P_t = price in period t and

D_t = dividends in period t

The shares were chosen intuitively from the set of larger industrial companies. Since this was to be a pilot study, no attempt was made to randomise or to choose representative shares from each of the market segments. The set can thus not be taken to necessarily represent the industrial share market. The companies chosen are given in table 1.

Table 1 COMPANIES USED IN THIS STUDY

BFA Ref. No.	COMPANY	SEGMENT
D0029	De Beer Industrial	Chemicals
P0199	Premier Milling	Food
R0017	Rembrandt Beh.	Tab. and Match
S0047	S.A. Breweries	Beverages
B0052	Barlow Rand	Ind. Holdings
S0330	Sentrachem	Chemicals
A0103	AECI	Chemicals
P0253	Protea Holdings	Ind. Holdings
A0073	Adonis Knitwear	Clothing
S0578	Stewarts and Lloyds	Engineering
T0115	Tollgate Holdings	Ind. Holdings

6.2. MARKET AND ECONOMIC INDICATOR DATA

The following data sets were obtained from the Financial Mail. The magazine is published weekly on a Thursday and lists prices and indeces for the preceeding Tuesday. Starting with January 1970, the values are those on the Tuesday closest to the begining of the month.

S.A. Industrials Composite,
U.K. Industrials, Financial Times,
U.S. Industrials, Standard and Poors 425,
Eurosyn Index,
U.S. Industrials, Dow Jones and
Manufacturing production index (not seasonally adjusted)

The following data sets were obtained from the South African Reserve Bank Quarterly Bulletin -

Bank acceptances 90-day,
Money and near money,
Consumer price index,
Bank debits and
Physical volume of production index (seasonally adjusted)

Several of the indeces were initially based on 1963 but changed later to 1970. An appropriate multiplier was used to make the base 1963 throughout.

6.3. CONDITIONING OF DATA

If the spectrum is taken of a series which has trend, it will be characterised by high values at the low frequency end. In addition the problem of "leakage" from these low frequencies will distort the power in higher frequencies. To overcome this problem, a logarithmic transformation and first differencing were applied to all series except those for earnings. The computer programme that was used, required that the data be input in card image and formatted in a way that limited the input to 3 figures after the decimal point. Since the log-differencing scheme produces small numbers, it was necessary to further condition the series by multiplying by 1000. Earnings were expressed as percentages. The series which were subject to the spectral analyses were thus generated by

$$Y_t = (\ln X_{t+1} - \ln X_t) \times 1000$$

where Y_t is the new series at time t,

ln is natural logarithm and

X_t is the raw data series at time t

The programme further required an even number of points and consequently Y_{96} was set to zero.

6.4. THE COMPUTER PROGRAMME FOR SPECTRAL ANALYSIS

The programme used was "TYDREEKS" [1] which derives spectra and cross-spectra from the basic definitions rather than through a technique such as the Fast Fourier Transform algorithm. It is nevertheless adequately efficient on series such as those of this study, where the sample space is only 96 points. The programme uses the Parzan Lag window in the estimation and permits any number of lags to be chosen, although in this study one quarter of the sample size, i.e. 24, was used throughout. Spot checks using fewer lags indicated that no different interpretation would be placed on the results.

A particular feature of the programme is that it estimates the 95% confidence limits of each of the functions. The calculation is based on the assumption of normality and contains other approximations and is, therefore, not strictly accurate, but is nevertheless invaluable in determining the significance of the results.

6.5. BIAS IN THE DATA

The use of the Financial Mail as a convenient source for the data introduces the problem that the sample point is the Tuesday nearest

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1) Erasmus, C.M., "Tydreeks - 'n interaktiewe fortran program vir tydreeksontleedings-gebruikshandleiding", Institute for Econometrics University of Pretoria, Publication No. 13, September 1978.

the beginning of the month and not the true start of month. The interval between sample points is thus sometimes four and sometimes five weeks. Since this study investigates periods of longer than two months, it is assumed that this effect will be negligible.

The share prices used for individual shares represents a weighted average for all transactions in that month. The averaging process must necessarily give rise to autocorrelation as the prices towards the end of the month will be reflected in the prices in the first part of the next month.

It has already been stated supra that the sample of individual shares chosen cannot be considered a random sample of the market.

The ninety-day banker's acceptance rate is changed from time to time and is a step, rather than a continuous function. The value used in this study was the value at the beginning of the month.

CHAPTER 7

PRESENTATION AND INTERPRETATION OF RESULTS

7.1. SPECTRA OF INDECES

The spectrum of the South African Composite Index from the Financial Mail is shown in figure 1. This is sufficiently flat to indicate that the process is random, although minor peaks occur at periods of 8,4 and 3 months. The model which was chosen produces the spectrum of the first differences, i.e. changes. This may also be written as (see para. 2.3.)

$$X_{t+1} - X_t = \mathcal{E}_t$$

The spectrum shows that, where the composite index is used as a measure of the market, the series $\mathcal{E}_t$ is random. Further, $\mathcal{E}_t$ has a mean of -1,6 and a standard deviation of 62.8. While co-variance stationarity has not been established, this evidence supports the random walk hypothesis.

By contrast the spectrum of the Financial Times Composite Index on the London stock exchange (fig. 2) shows an extremely marked peak at the 4,3 month period and a lesser peak at 3 months. This latter is probably an harmonic. This indication of strong cyclic components is not reflected in the analyses on the London stock exchange by Kendall [1], Kemp and Reid [2], or Solnik [3].

This can largely be attributed to the difference in methods and the data bases used. Kendall used the weekly indeces of various sectors rather than a composite index for the 9 years between 1928 and 1937. Kemp and Reid used daily prices for a three month period and would thus not be able to detect longer periods. Solnik used serial correlation tests on earnings calculated over a maximum period of one month and would thus also not detect 3 month or longer periodicities.

The spectra for both the Dow Jones (fig. 3) and Standard and Poor (fig. 4) indeces show a relatively well defined peak at the 12 month period and a wider peak around 3 to 4 months. The concentration of "power" around the latter period can reasonably be attributed to the American practice of quarterly dividend declarations. The logarithmic transformation makes appreciation of the magnitude of the power spectrum difficult but it is the writer's interpretation that the variation is not sufficient to suggest exploitable non-random behaviour especially when cognisance is

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1) Kendall, M., "The analysis of economic time-series - Part 1 : Prices", Jnl Royal Statistical Society, Vol. 96, Part 1(1953) p.11-25 as reprinted in Cootner, P.H.(ed), op.cit.,p.85

2) Kemp, A.G. and Reid, G.C., "The random walk hypothesis and the recent behaviour of equity prices in Britain", Economica, Feb 1971, p.28-51.

3) Solnik, B.H., "Note on the validity of the random walk for European stock prices", Jnl of Finance, Dec 1973, p.1151-1159.

taken of the extent of the confidence limits. It is noted that the spectral results of Granger and Morgenstern [4] for the SEC Composite Weekly Index (1939 - 1961) also show a peak above the significance test line, albeit a weak one, at approximately the same frequency. The suggestion of non-random behaviour about a frequency determined by quarterly earnings reports has already been made by Jones and Litzenberger [5].

The spectrum of the Eurosyn Index (fig 5) shows a weak peak at the annual period and a strong peak at 3 months. The narrowness of this latter peak suggests a fairly well defined cyclic component at this frequency. Unfortunately the writer has not found any analyses of this particular index which could be used for comparison. The work of Solnik [6] was based on daily prices of individual shares. His conclusion that European exchanges exhibit more non-random behaviour than NYSE leads to the expectation that the spectrum would have more defined peaks than the equivalent for the Dow Jones or Standard and Poor indeces.

The spectrum of the consumer price index (fig. 6) has a large component at the low frequencies. This characteristic is attributable

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4) Granger, C.W.J. and Morgenstern, O., "Spectral analysis of stock market prices", Kyklos, Vol. 16. 1963(1), p.10.

5) Jones, C.P. and Litzenberger, R.H., "Quarterly earnings reports and intermediate stock price trends", Jnl of Finance, March 1970 p. 143

6) Solnik, B.H., op.cit.

to the fact that the differencing model has not sufficiently eliminated the effects of trend. This is consistent with the fact that the index is monotonically increasing and that the percentage increases have not changed in magnitude but that the absolute changes have increased. The spectrum of the differenced series is characteristic of a first order auto-regressive process of the form

$$X_t = \alpha X_{t-1} + Z_t \quad \text{with } \alpha > 0$$

The spectrum for bank debits (fig. 7) shows the opposite in that all of the power is concentrated towards the higher frequencies. A peak is present at a frequency of 3 months. This suggests that this indicator is highly volatile. This spectrum of the differenced series is characteristic of a first order moving average process of the form

$$X_t = Z_t + \beta Z_{t-1} \quad \text{with } \beta < 1$$

The spectrum for the interest rate on 90-day bankers acceptances (fig. 8) has somewhat higher values in the low frequencies and a minor peak near 6 months but can be taken to indicate a random series.

The spectrum for the supply of money and near money (fig. 9) shows a strong peak at 3 months and a tendency towards more power in the higher frequencies. This indicates the quarterly review that the authorities make of this economic quantity when adjusting it as an instrument of monetary policy.

The spectrum of the index of manufacturing production (fig. 10) obtained from the Financial Mail and which is a non-seasonally adjusted figure, shows a significant peak at 4 months and a lesser peak at 3 months. No explanation can be offered as to why this should be so. The spectrum of the physical volume of production index (fig. 11) which was obtained from the Reserve Bank Quarterly Bulletin shows the experimental shape characteristic of auto-correlation processes with negative constant. The high peak at 3 months which is not found in the non-seasonally adjusted spectrum suggests that the adjustment procedure introduces this cyclicity to the data. This problem has been reported by Nerlove [7)].

7.2. SPECTRA OF SHARE PRICES AND EARNINGS

Figure 12 is the share price spectrum of Sentrachem and figure 13 is the earnings spectrum. It can be seen that the shape of the spectra are essentially the same. This was in fact found for all

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7) Nerlove, M., "Spectral analysis of seasonal adjustment procedures" Econometrica, July 1964, p.241-266.

of the companies considered and it was thus concluded that the results of cross-spectral analysis with either could equally apply to the other and consequently only the price spectra are discussed further.

The Sentrachem price spectrum is characterised by a minor peak near to the annual periodicity and a slightly more significant one near to 3 months. The same tendency was shown by Premier Milling and Barlow Rand (not shown here). The price spectra of SA Breweries (fig. 14) and Protea Holdings showed similar mild peaks with the one near the annual period somewhat stronger. Because of the weakness of these peaks and bearing in mind the extent of the confidence limits, it would not be possible to formulate significant models for prediction in the time-domain.

The price spectra of Rembrandt Holdings (fig. 15) and Stewart and Lloyds were so level as to suggest a random behaviour.

The price spectra of de Beers Industrial (fig 16) and Adonis Knitwear increase towards the higher frequencies indicating volatile prices.

The shares that do show the presence of single strong periodic components are Tiger Oats (fig. 17), AECI (fig. 18) and to a lesser extent Tollgate (fig. 19). The first mentioned peaks at 9,6 months, the second at 8,0 months and the third at 5,3 months. These peaks are sufficiently defined to suggest that a cyclic model, centered on these frequencies, may well be able to account for a considerable part of the variation in the price of these shares. This, however, lies outside the area of the present study.

Taken together, the spectra for the individual shares indicate that most price series show some measure of an annual frequency component, but that it is unlikely that this is of sufficient magnitude to be exploited in a general model in the time-domain.

7.3. CROSS SPECTRA OF INDECES

The interpretation of the cross spectra invloved the following steps:-

- The examination of the coherency. It will be recalled from para 5.7. that the coherency is comparable to the correlation coefficient with a value of unity denoting perfect correlation. In many of the results it was found that the 95% lower confidence limit was zero. This means that the result is not statistically significant at the 5% level and the interpretation in this dissertation has been to disregard these results.

- The examination of the phase diagram to establish whether, at the points where there is significant coherency, there is a phase shift between the series. Again the question arises as to whether the confidence limits denote results which are statistically significant. Phase is the angular shift of the crossed (output) series relative to the base (input) series and positive values thus indicate that the base series leads.

- The examination of the gain spectrum. This quantity is analogous to the regression coefficient in a linear system and thus gives a measure of the amplification where in linear system terminology the base series is regarded as the input and the second series as the output.

A cross spectral analysis between the SA Industrial Composite Index and all the other indeces and indicators was performed first. The following table shows the maximum value of the coherency for those series where the 95% lower confidence level was greater than zero at 2 or fewer frequencies. The coherency spectrum for the UK Financial Times index is given in figure 20 as an example of this class.

Table 2 : CROSS SPECTRAL RESULTS OF INDECES WITH 2 OR FEWER SIGNIFICANT POINTS

Crossed Series	Maximum Coherency	Frequency (months)
UK Financial Times	0,48	2,4
Manufacturing Volume (FM)	0,56	12,0
Consumer Price Index	0,56	5,3
Bank Debits	0,65	48,0

The base series in all cases was the SA Industrial Composite

The coherency spectrum for the SA Industrial Composite with the Dow Jones (fig. 21) and Standard and Poors Indeces showed a number of points where the 95% lower confidence limit was greater than zero but only marginally so. This is evident in the periodicities between 6 and 24 months. Reference to the phase diagram (fig. 22) for the SA Composite as the base (input) series and Dow Jones as the output series, shows that except between periodicities of 6 months to 12 months the former lags. It should, however, be noted that significant coherencies occur at 3,6, 4,0, 6,8, 12,0 and 16,0 months. However, the confidence limits of the phase spectrum straddle the zero and no deductions can thus be made. The estimate of phase does, however, show a downward trend and if a straight line is fitted by eye through the origin and the majority of points, a constant phase delay of 0,8 months can be deduced.

Compared to the above cross-spectra, the Eurosyn Index shows a number of significant coherency points (fig. 23), in the ranges 3,2 months to 6 months and 12 months to 48 months. The maximum coherency value is 0,84. The phase diagram is shown in figure 24. There are three points centered at 4 months where the Eurosyn Index leads the SA Composite by the statistically significant amount of 0,95 radians (0,6 months). Other values are not significant. The gain diagram (fig. 25) shows a value of 0,3 in this frequency band. This low value is indicative of the relative steadiness of the Eurosyn Index. The inverse relationship suggests that changes in the Eurosyn Index will be amplified 3 times on the JSE.

Significant coherency also exists at a number of points for the SA Composite and the Bank Acceptances Interest Rate. It is noteworthy that coherency is highest at the lowest frequencies reaching 0,78 at 48 months. There are, however, no points on the phase diagram which are significantly different from zero. Indeed, the estimated values vary about the origin.

7.4. CROSS SPECTRA OF SHARE PRICES WITH SA COMPOSITE INDEX

Most of the individual shares have high coherency with the index, particularly on the lower frequency end. Table 3 summarises the results.

Table 3 : CROSS SPECTRAL RESULTS OF INDIVIDUAL SHARES WITH SA COMPOSITE

SHARE	COLUMN NUMBER							
	1	2	3	4	5	6	7	8
	No.		Month	No.	Month	Month		
De Beers	1	0,58	5,3	0	-	-	2,3	
Premier Milling	15	0,87	24,0	12	2,2	5,3	1,4	1,19
Rembrandt	21	0,85	3,7	14	1,6	3,4	1,6	1,27
SAB	21	0,89	9,6	14	1,6	3,4	1,6	1.17
Barlow Rand	15	0,89	48,0	6	1,7	3,4	1,6	1,31
Sentrachem	17	0,93	8,0	10	1,0	3,7	1,2	0,91
AECI	14	0,83	5,3	12	1,2	2,6	1,0	0,87
Protea Holdings	11	0,77	8,0	3	2,1	5,3	1,3	
Adonis	3	0,88	48,0	0	-	-	1,7	
S & L	14	0,84	9,6	5	1,5	3,2	1,4	0,90

Legend

Col. 1 Number of points on the coherency spectrum where the lower 95% confidence limit was greater than zero

Col. 2 Maximum value of coherency

Col. 3 Period of maximum coherency

Col. 4 Number of phase points which are statistically different from zero.

Col. 5 Maximum phase shift of significant phase points

Col. 6 Period at maximum phase shift

Col. 7 Maximum gain

Col. 8 Beta volatility index

The coherency, phase and gain spectra of Sentrachem with the index are included as figures 26, 27 and 28 as typical of this analysis.

The fact that all of the individual shares have high coherency with the market, is to be expected, particularly at the lower frequencies. At higher frequencies the prices of shares move more independantly than the market index but are subject to the longer term trends. The shares selected all appear to lead the index at lower frequencies while at the higher frequencies some lead, although most lag. Obviously overall there must be as many shares leading the index as lagging it. The tendency to lead, as shown by the shares selected, is attributed to non-randomness in the sampling.

The comparison between the gain and the volatility index, beta, can be made intuitively since both represent the amount that the one variable will change relative to a change in the base variable. The value in the above table is, however, at a specific frequency and does not represent the response over the full bandwidth. Nevertheless, the higher values of beta tend to be associated with higher values of gain.

Except at the highest frequencies, the phase spectrum of Barlow Rand is particularly linear (fig. 29). A linear phase spectrum indicates a tendency to pure delay, i.e. a delay by a constant time interval. The time interval can be derived from the slope of the spectrum and for this share is 1,0 months. The fact that the share price sample is taken as the average during the month, whereas the index is the value at the start of the month, means that this lead time will in fact be larger.

7.5. CROSS SPECTRA OF SHARE PRICES WITH THE BANKERS ACCEPTANCE RATE.

The Bankers Acceptance Rate was chosen as representative of the cost of money in the economy and could thus possibly be an indicator of share prices. The results are summarised in table 4.

Table 4 : CROSS SPECTRAL RESULTS OF INDIVIDUAL SHARES WITH 90-DAY BANKERS ACCEPTANCE RATE

Share	Column Number		
	1	2	3
	No.	Months	
De Beers	7	2,2-2,8	0,81
Premier Milling	10	5,3-48,0	0,78
Rembrandt	2	4,3-4,8	0,60
SAB	11	3,7-5,3 8,0-48,0	0,70 0,70
Barlow Rand	8	4,3-5,3 6,8-12,0	0,61 0,62
Sentrachem	6	3,4-3,6 4,3-5,3	0,65 0,66
AECI	4	Spread	0,74
Protea Holdings	0	-	-
Adonis	2	24,0-48,0	0,84
S & L	4	2,1-2,4	0,72
Tiger Oats	8	3,4-4,0 8,0-16,0	0,63 0,72

Legend.

Col. 1 Number of points on the coherency spectrum where the lower 95% confidence limit was greater than zero.

Col. 2 Period for points in Col. 1.

Col. 3 Maximum coherency.

Only isolated points occurred on the phase spectra which were significantly different from zero and thus no lead/lag interpretations could be made. The coherency and phase spectra for Tiger Oats, which were the most significant results obtained, are included as figures 30 and 31.

7.6. CROSS SPECTRA OF SHARE PRICES AND OTHER INDECES

The individual share prices were further analysed with the following indeces as base series:-

- consumer price index,
- supply of money and near money,
- bank debits,
- manufacturing volume index (Financial Mail) and
- physical volume of production (Reserve Bank)

Only isolated cases of statistically significant coherencies occurred with peak values generally below 0,6. Thus within the limits of these tests there are no causual relationships between the individual share prices and these indeces. The link between the overseas indeces and individual share prices was considered too tenuous to warrant analysis.

The values of coherency found are consistent with the results of

Granger and Morgenstern who did not, however, apply the statistical significance test in reporting the weak link (see para. 4.3 supra).

7.7. VOLUME RELATIONSHIPS

No significant results were found when the base series was the SA Industrial Composite Index and the crossed series were the volume of shares traded.

The earnings of each share was then analysed with the volume traded as the base series. Only isolated points were observed where the coherency was significant at the 5% level. The coherency and phase spectra for Sentrachem are included as the most noteworthy result obtained (fig. 32 and 33). Of the other shares, Adonis, which was the share with the lowest traded volume, had 6 frequencies with significant coherency, the maximum being 0,70. No other shares had more than 4 significant values.

The lack of coherency between price and volume confirms the findings of Granger and Morgenstern reviewed in para 4.3. supra.

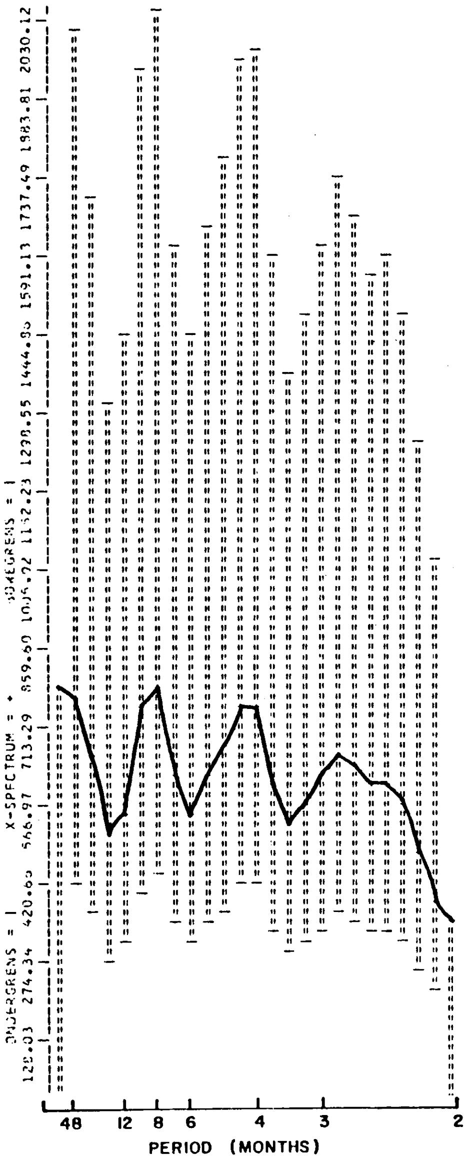


FIG 1. SPECTRUM OF INDEX

SA COMPOSITE INDUSTRIAL FM

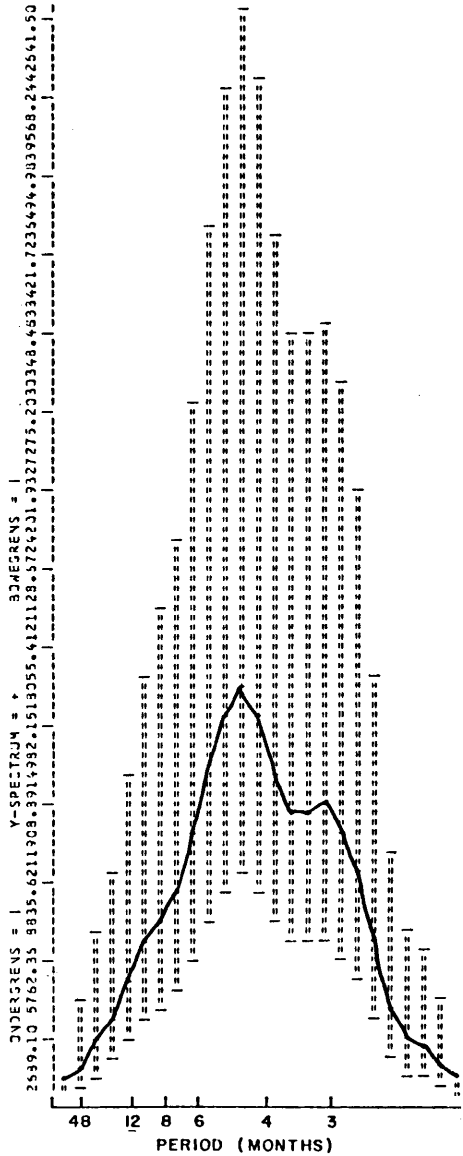


FIG 2. SPECTRUM OF INDEX

UK FINANCIAL TIMES INDUSTRIAL

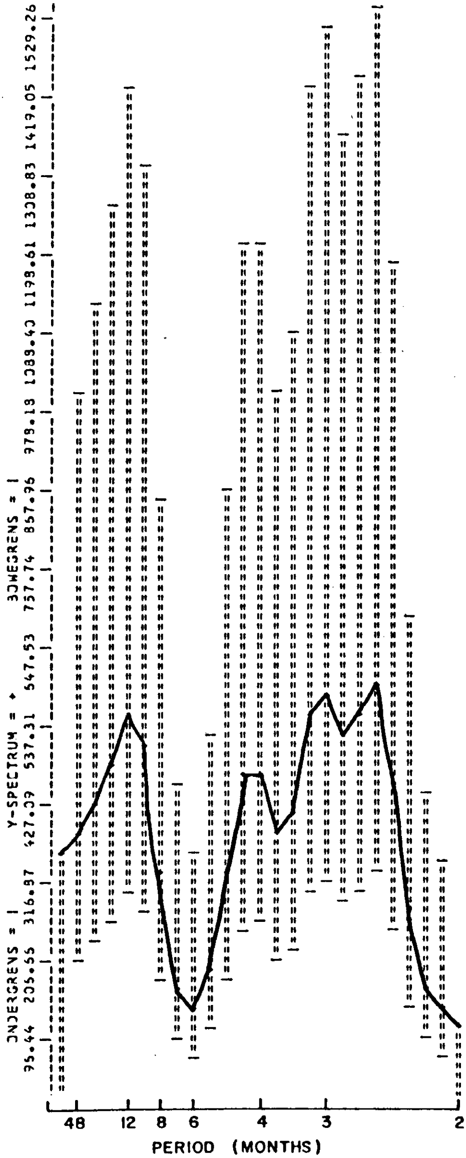


FIG 3. SPECTRUM OF INDEX

DOW JONES

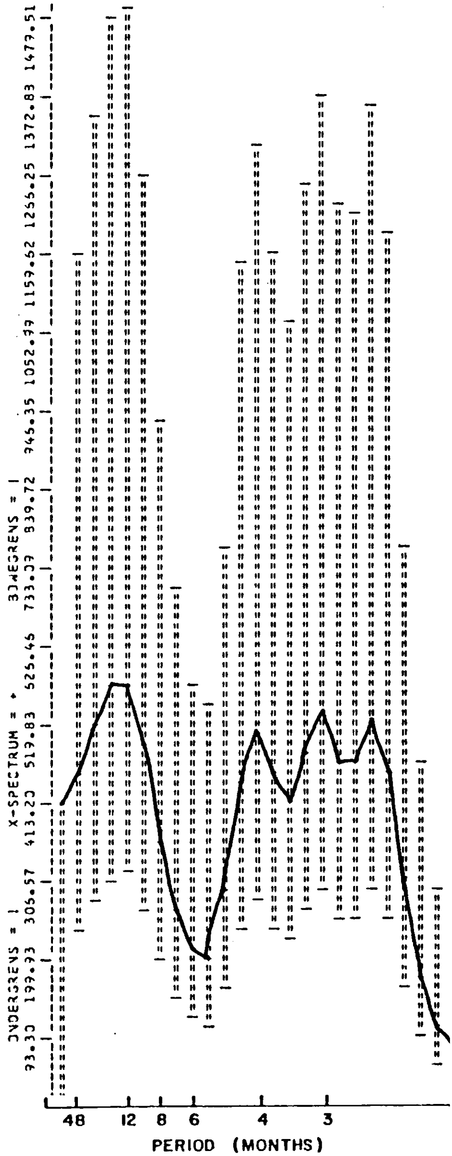


FIG 4. SPECTRUM OF INDEX

STANDARD AND POOR

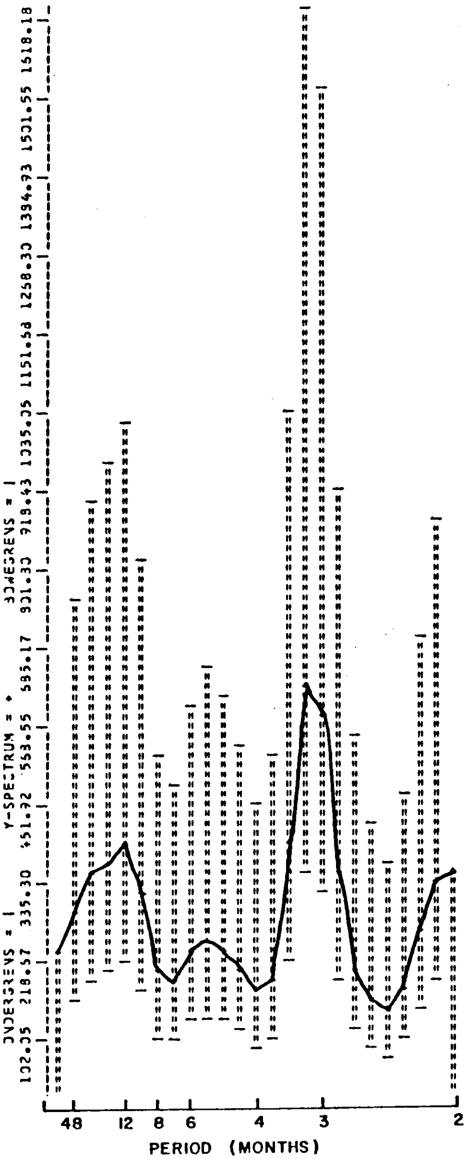


FIG 5. SPECTRUM OF INDEX

EUROSYN

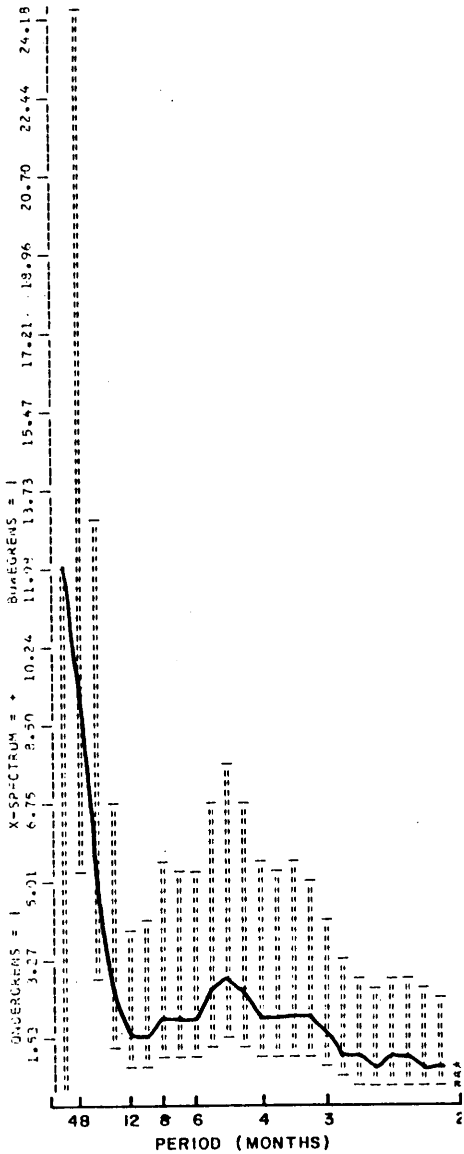


FIG 6. SPECTRUM OF INDEX

CONSUMER PRICE

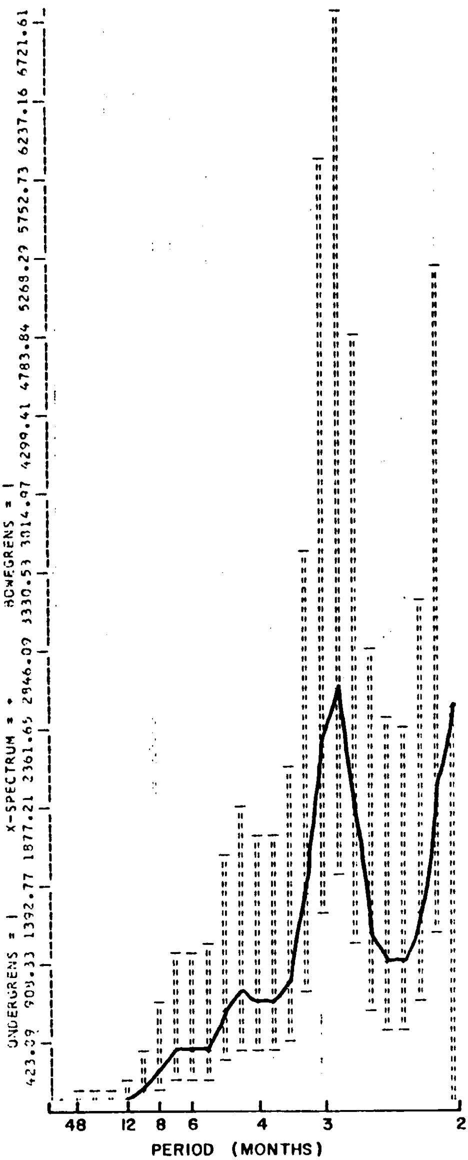


FIG 7 SPECTRUM

BANK DEBITS

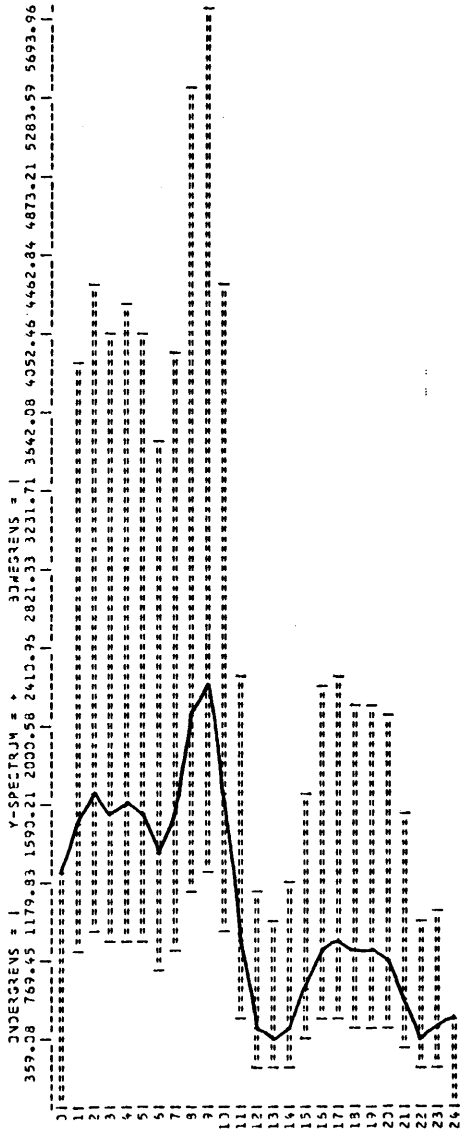


FIG 8 SPECTRUM

90 DAY BANKERS ACCEPTANCE RATE

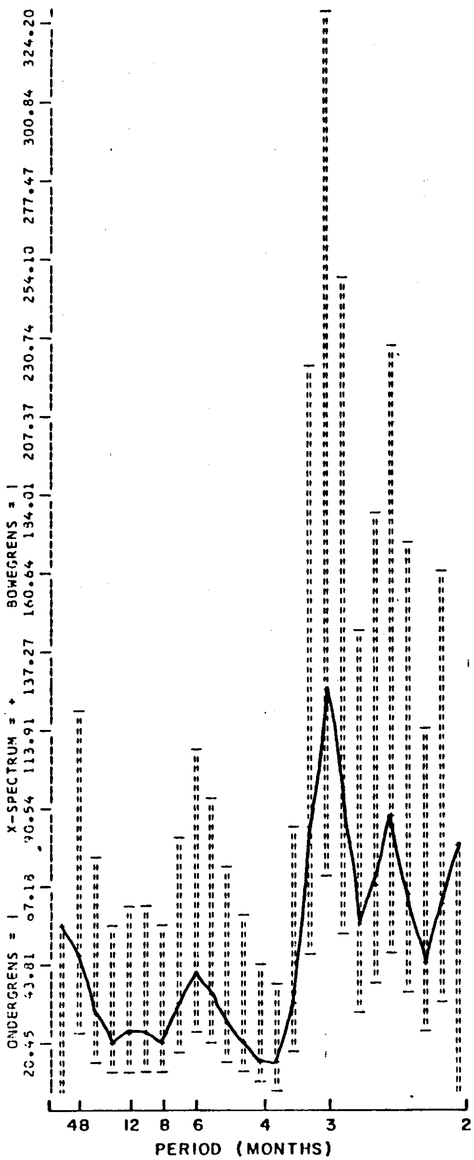


FIG 9 SPECTRUM

MONEY AND NEAR-MONEY

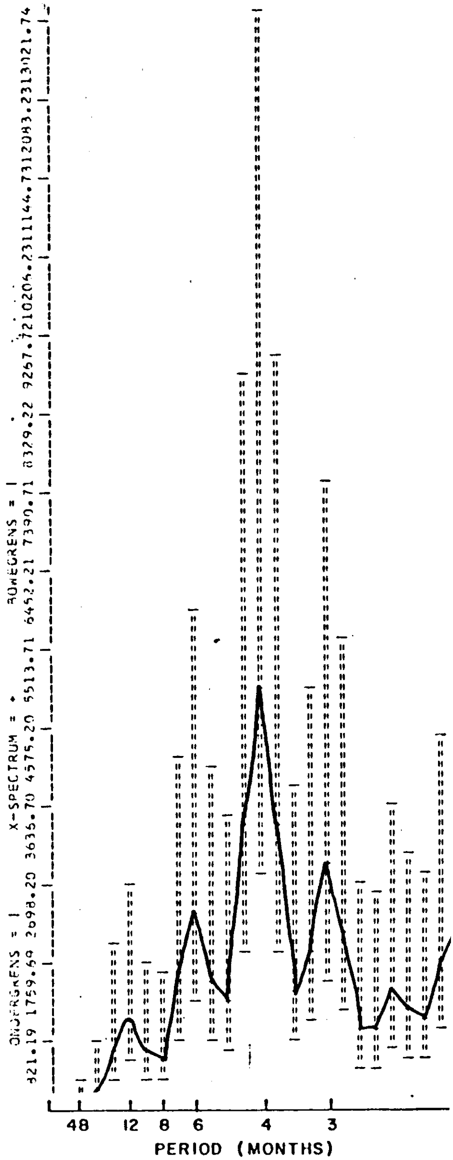


FIG 10 SPECTRUM OF INDEX

MANUFACTURING PRODUCTION (FM)

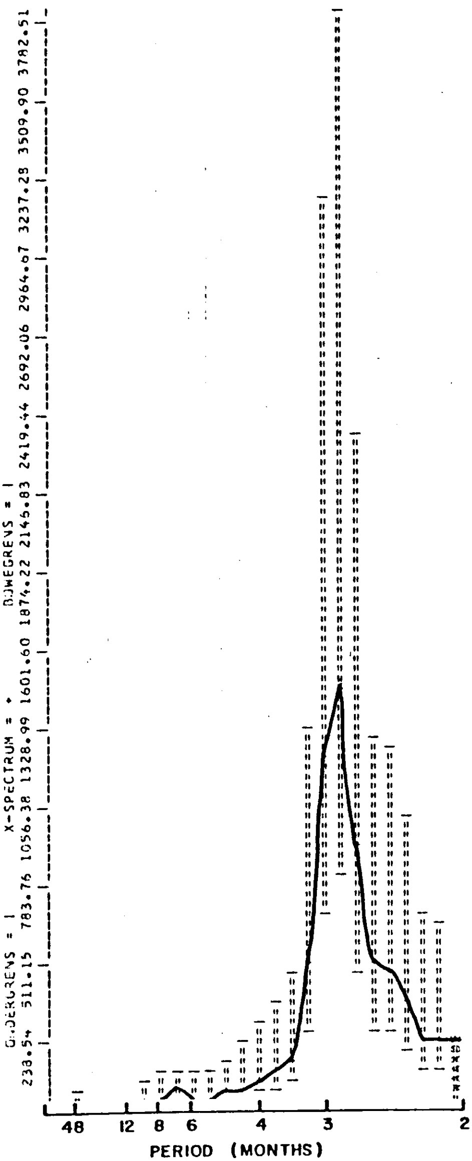


FIG 11 SPECTRUM OF INDEX PHYSICAL VOLUME OF PRODUCTION

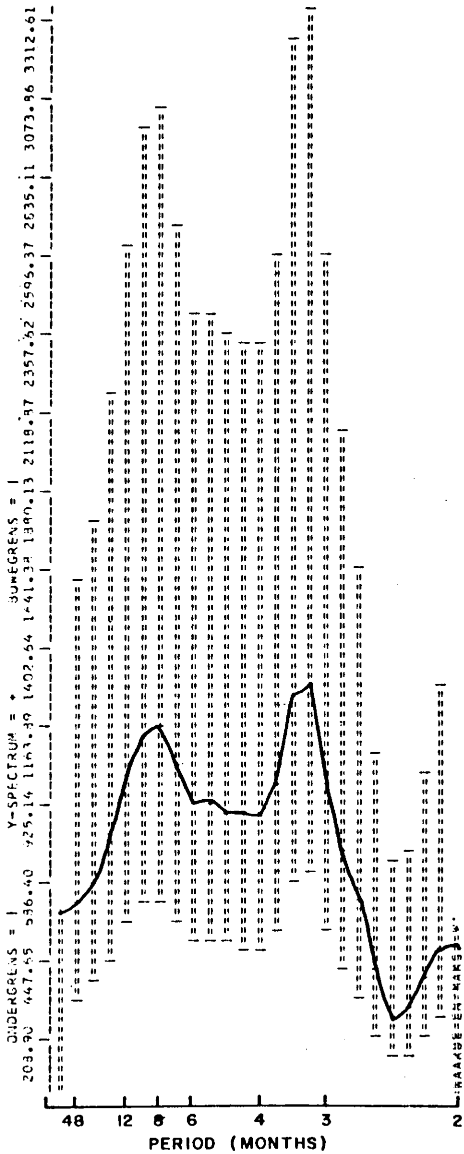


FIG 12 SPECTRUM OF SHARE PRICE SENTRACHEM

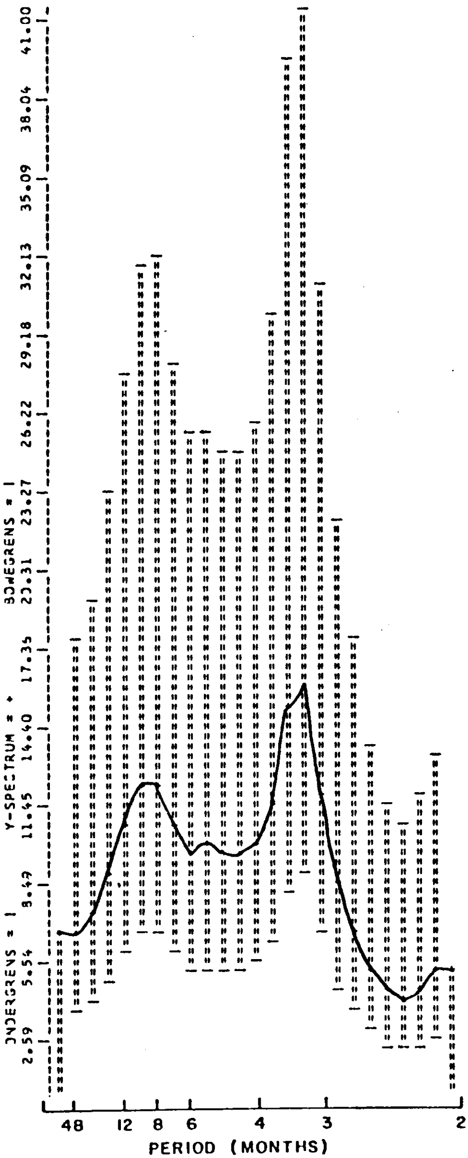


FIG. 13 SPECTRUM

SENTRACHEM EARNINGS

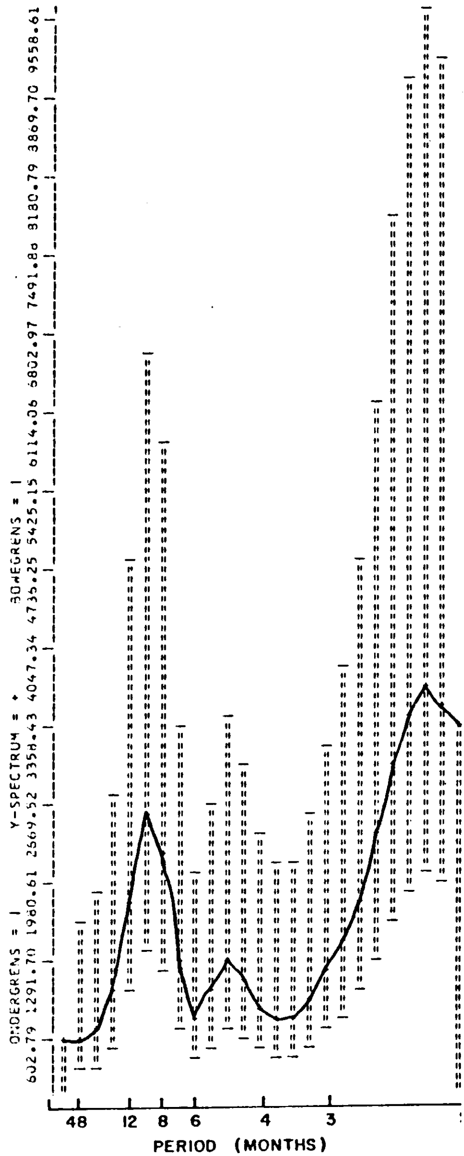


FIG. 14 SPECTRUM OF SHARE PRICE

SAB

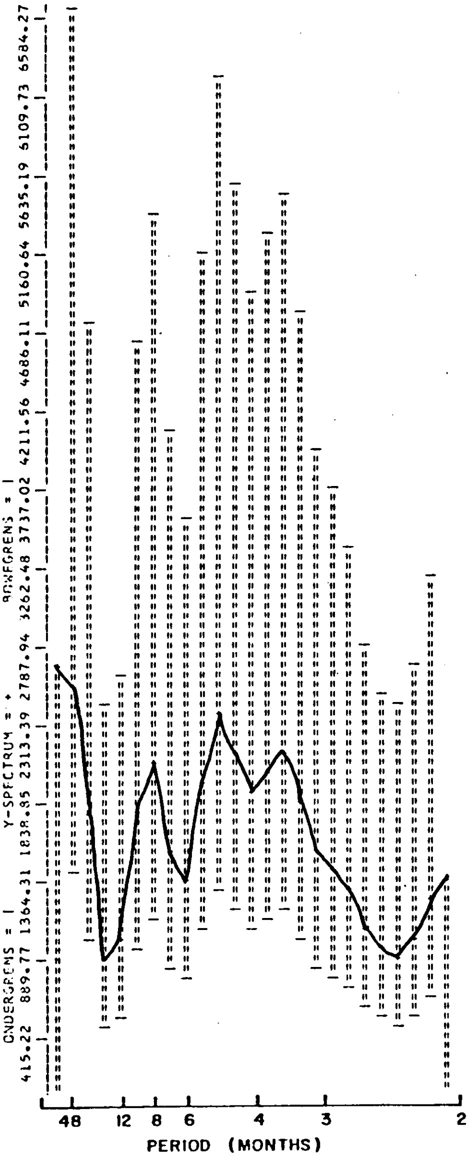


FIG. 15 SPECTRUM OF SHARE PRICE

REMBRANDT BEH

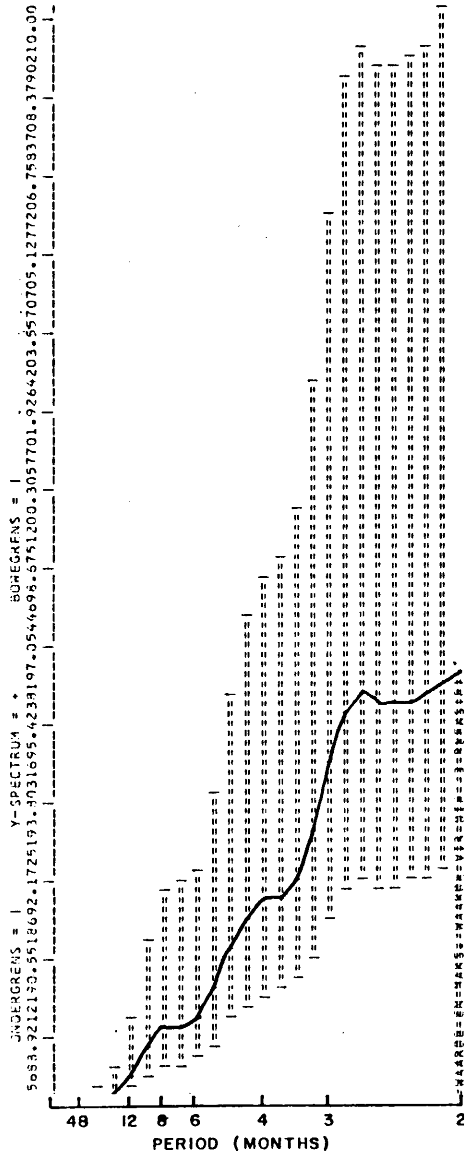


FIG. 16 SPECTRUM OF SHARE PRICE

DE BEERS IND

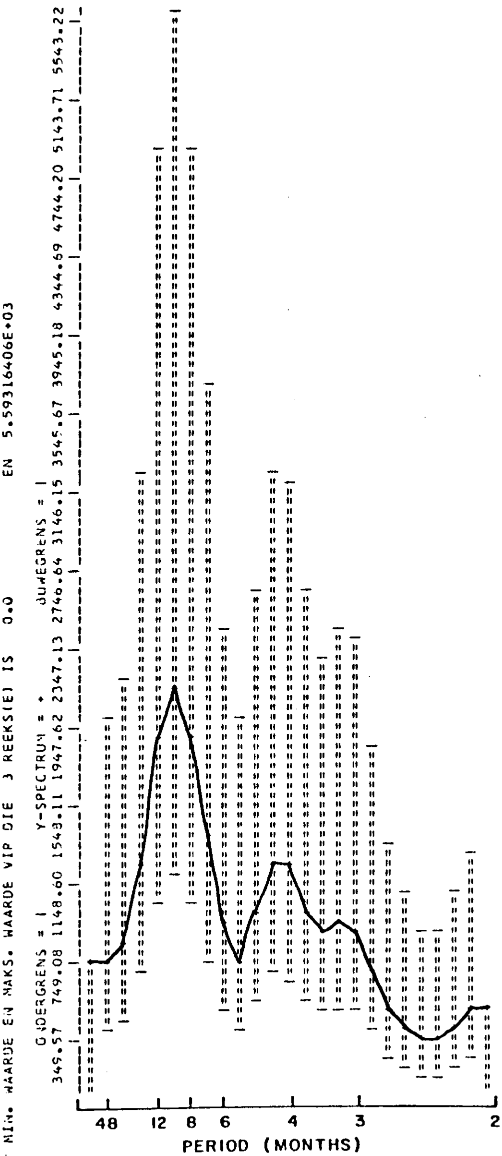


FIG. 17 SPECTRUM OF SHARE PRICE

TIGER OATS

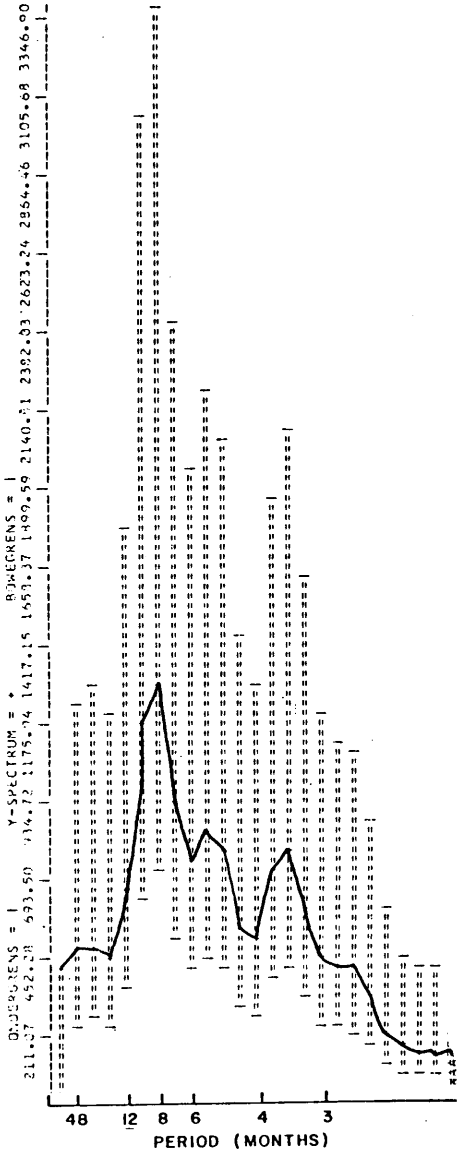


FIG. 18 SPECTRUM OF SHARE PRICE

AECI

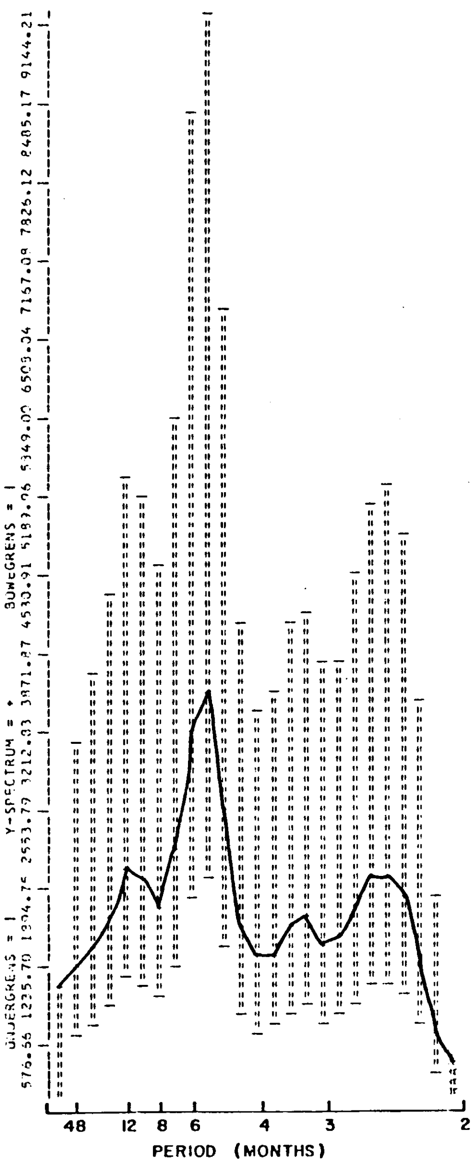


FIG. 19 SPECTRUM OF SHARE PRICE

TOLLGATE

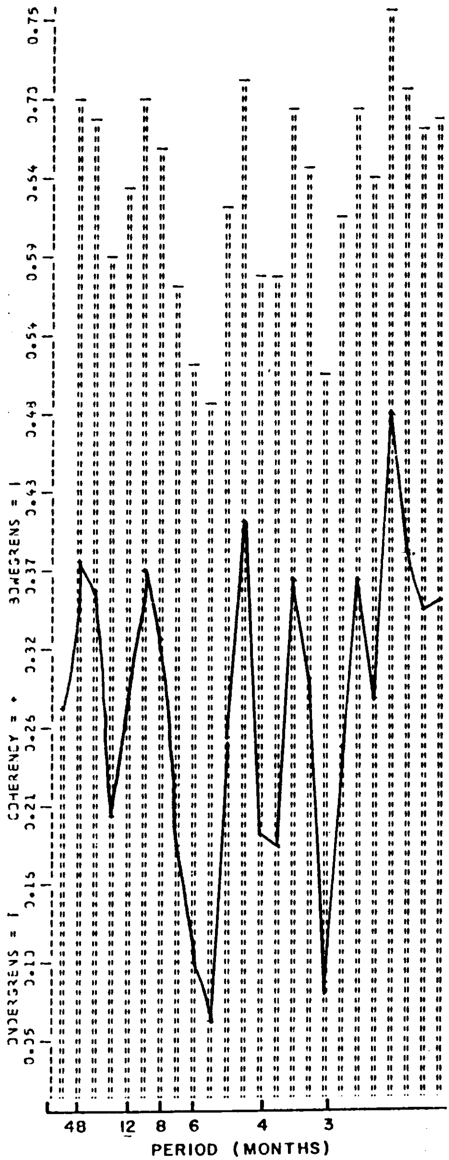


FIG. 20 CROSS SPECTRUM : COHEREN

BASE : SA COMPOSITE INDUSTRIAL I
CROSS : UK FINANCIAL TIMES INDUSTRI

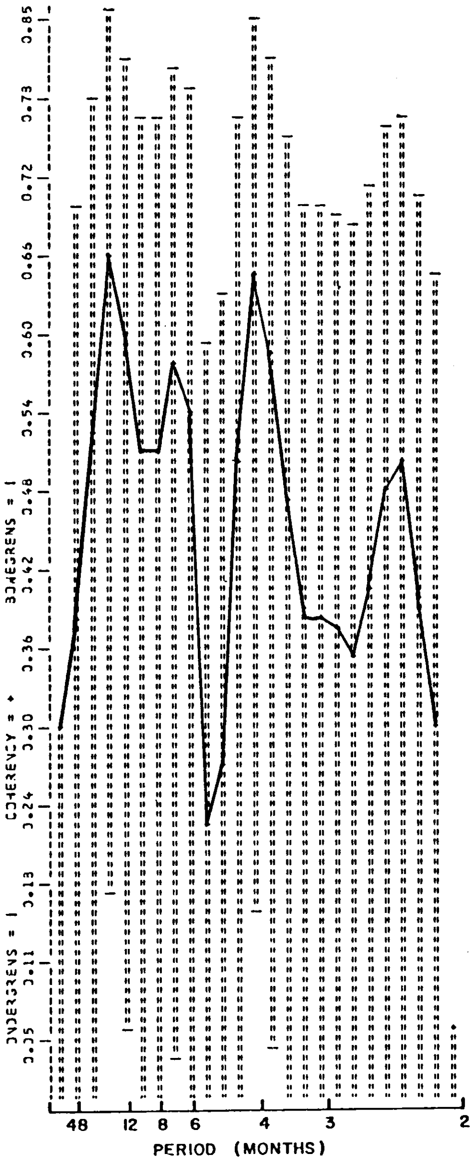


FIG. 21 CROSS SPECTRUM : COHERENCY

BASE : SA COMPOSITE INDUSTRIAL FM

CROSS : DOW JONES

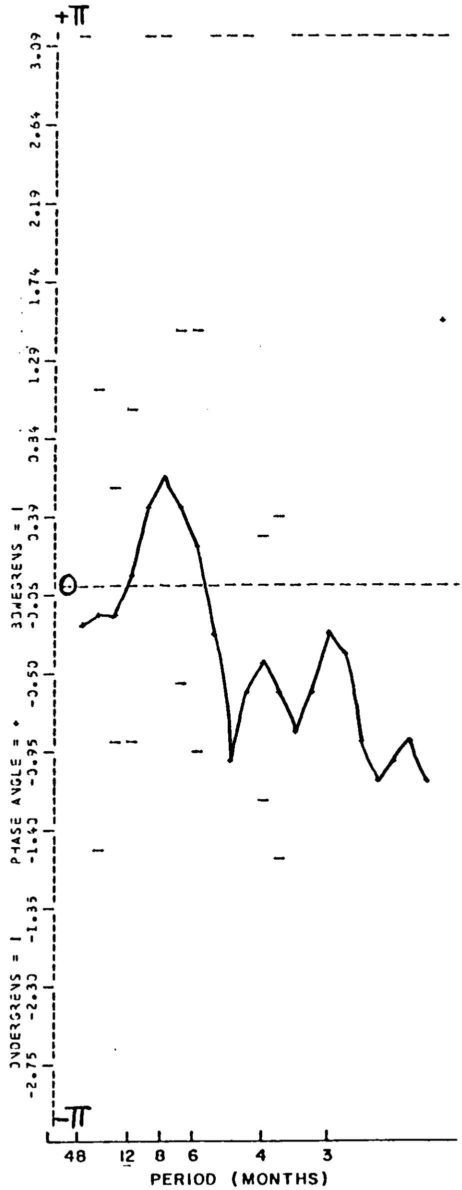


FIG. 22 CROSS SPECTRUM ; PHASE

BASE : SA COMPOSITE INDUSTRIAL FM

CROSS : DOW JONES

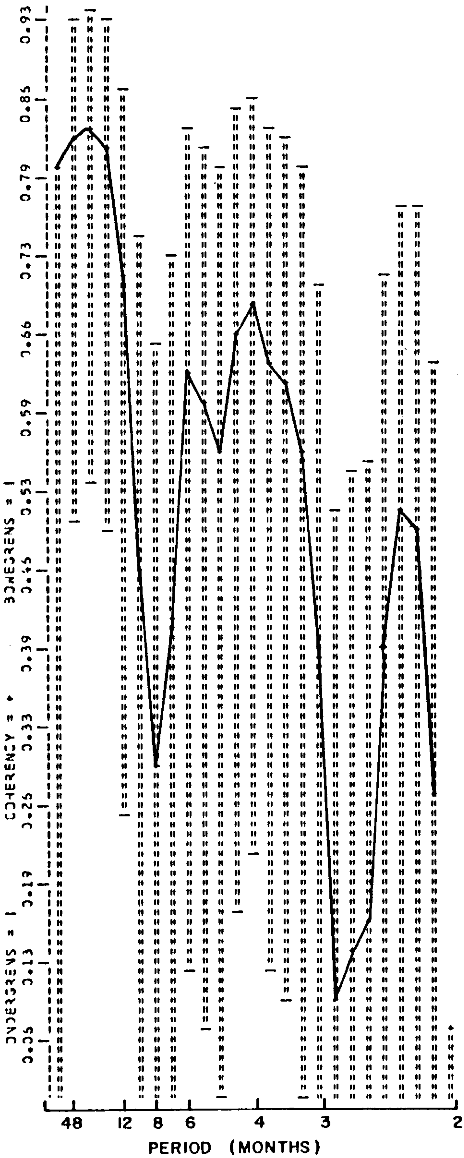


FIG. 23 CROSS SPECTRUM: COHERENCY

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : EUROSYN

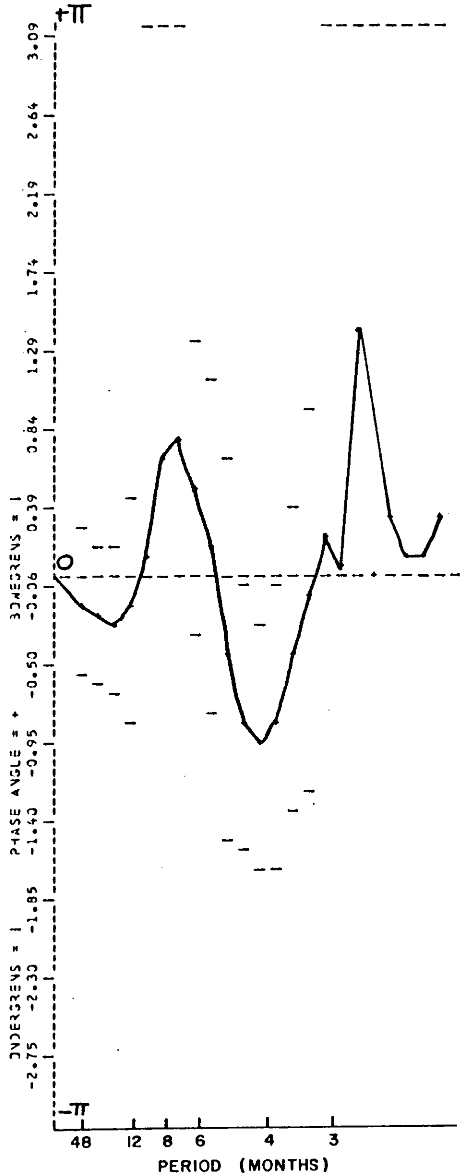


FIG. 24 CROSS SPECTRUM : PHASE

BASE : SA COMPOSITE INDUSTRIAL FI
CROSS : EUROSYN

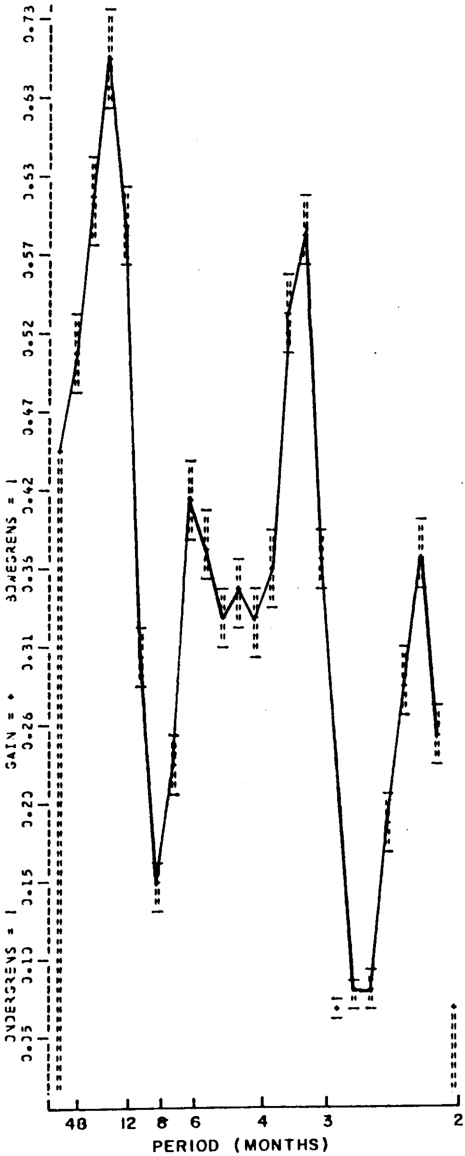


FIG 25 CROSS SPECTRUM : GAIN

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : EUROSYN

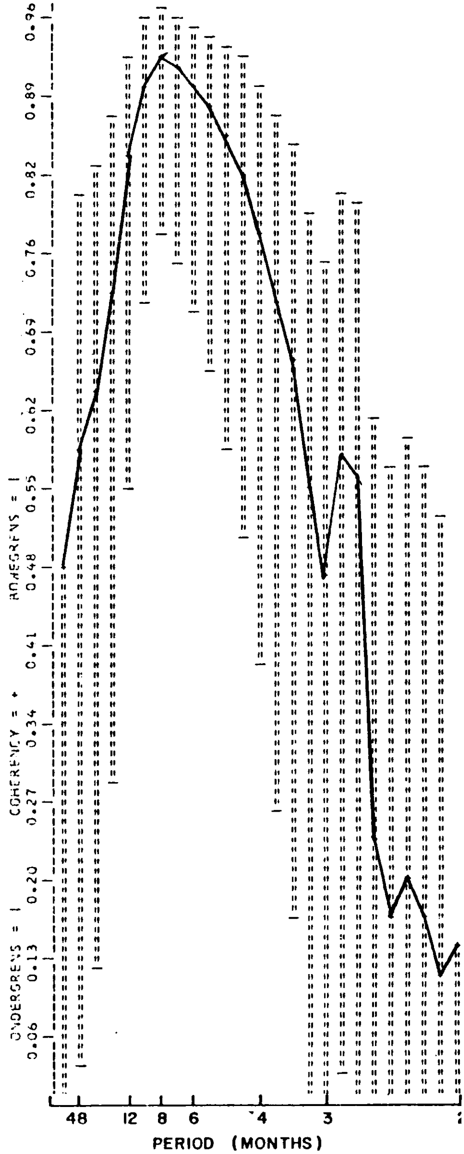


FIG 26 CROSS SPECTRUM : COHERENCY

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : SENTRACHEM PRICE

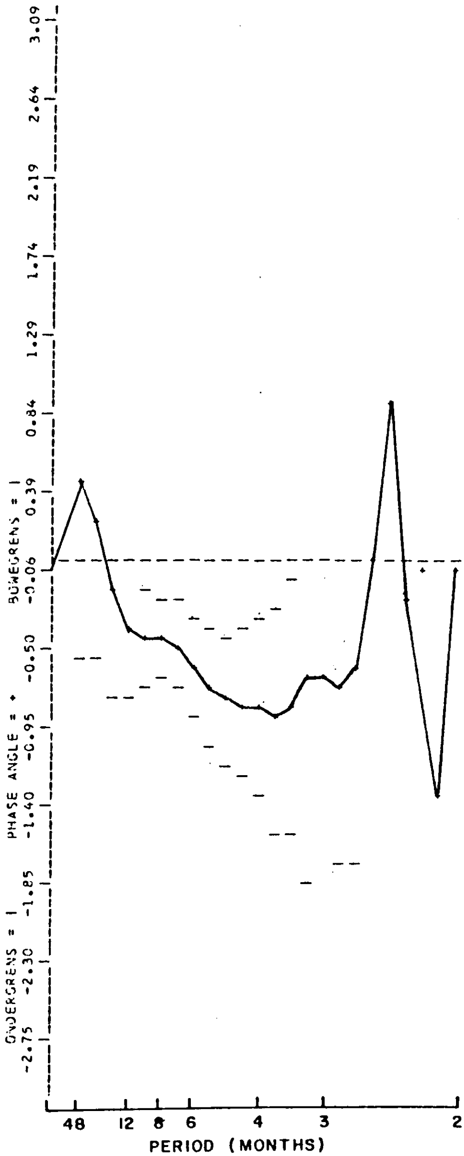


FIG 27 CROSS SPECTRUM PHASE

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : SENTRACHEM PRICE

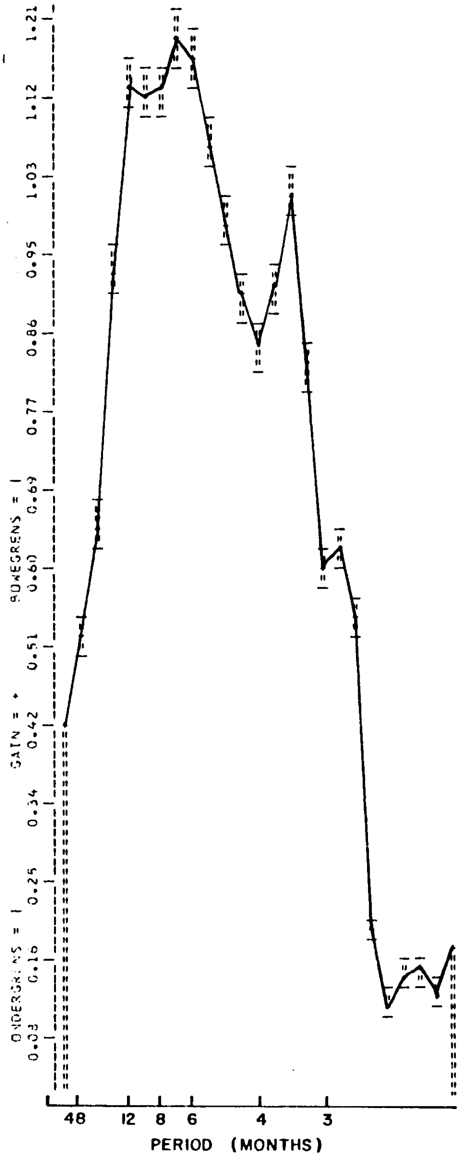


FIG 28 CROSS SPECTRUM : GAIN

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : SENTRACHEM PRICE

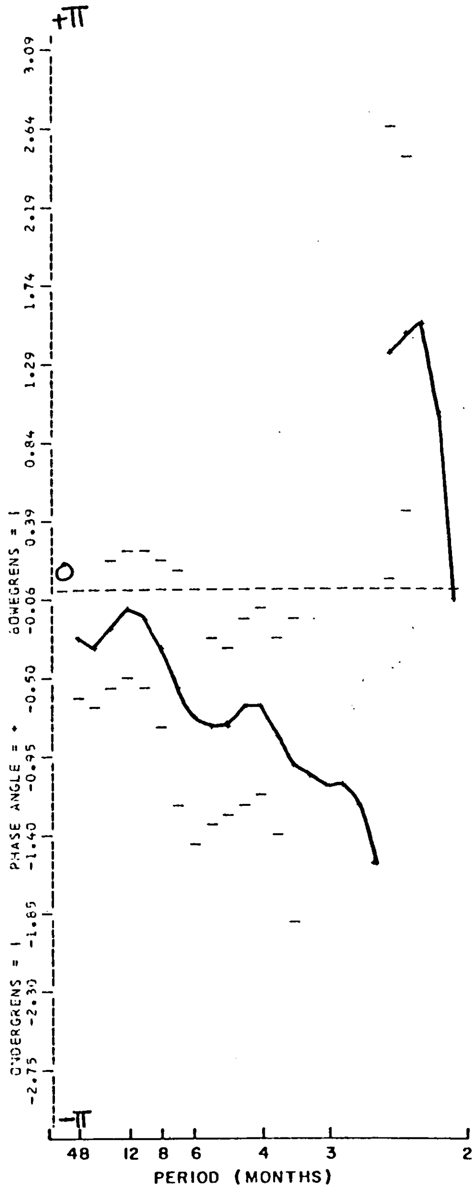


FIG 29 CROSS SPECTRUM PHASE

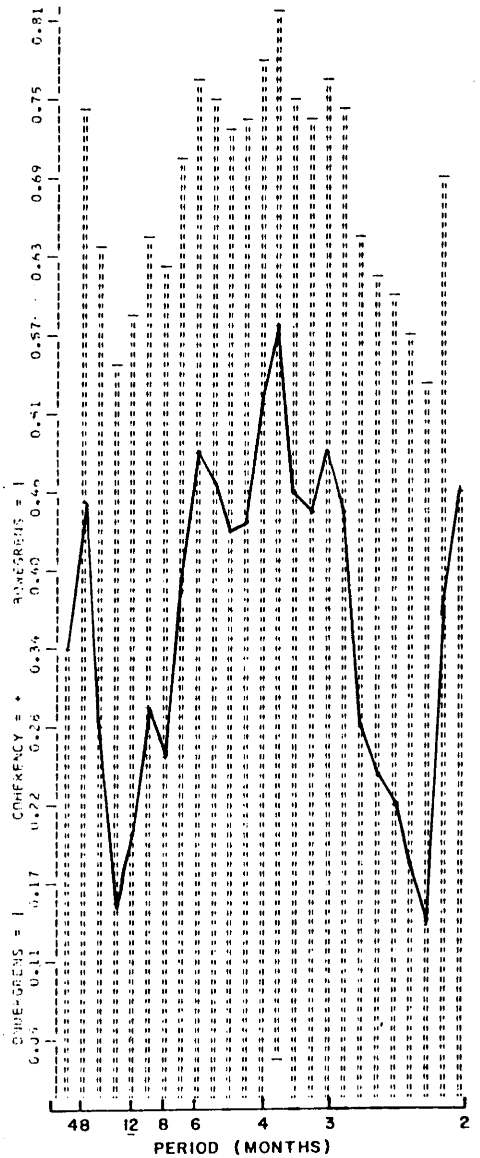
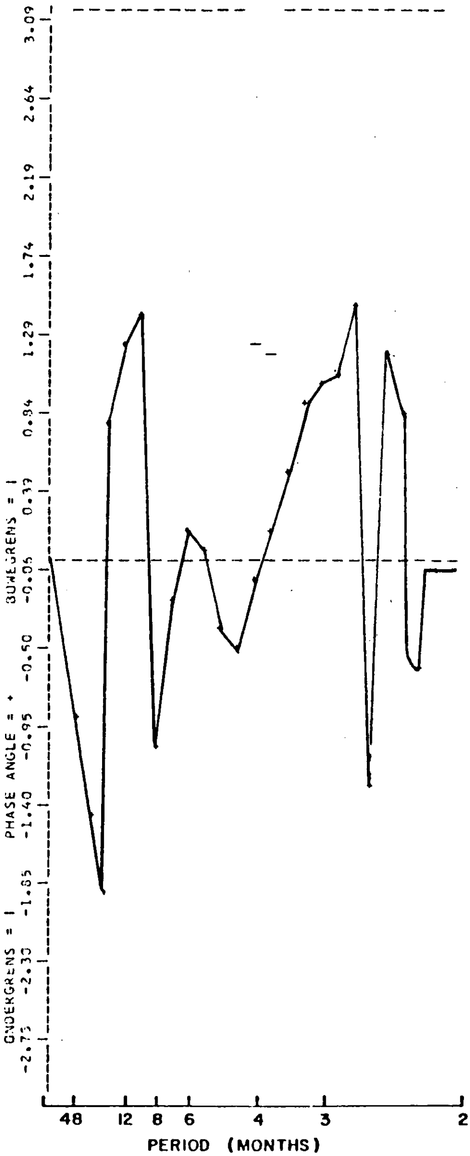


FIG 30 CROSS SPECTRUM COHERENCY

BASE : SA COMPOSITE INDUSTRIAL FM
CROSS : BARLOW RAND PRICE

BASE : 90 DAY BANKERS ACCEPTANCE RATE
CROSS : TIGER OATS PRICE



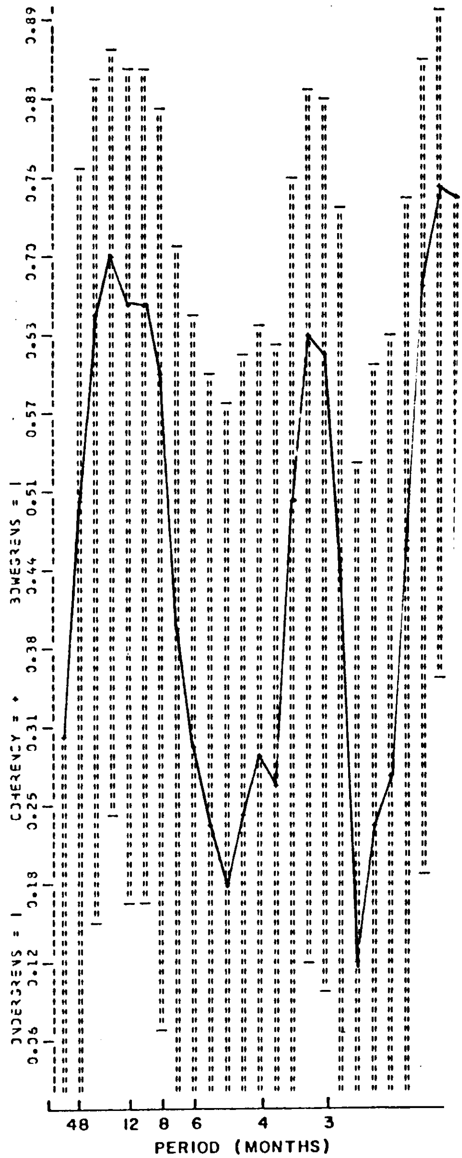


FIG 31 CROSS SPECTRUM PHASE

BASE : 90 DAY BANKERS ACCEPTANCE RATE
CROSS : TIGER OATS PRICE

FIG 32 CROSS SPECTRUM COHERENCY

BASE : SENTRACHEM VOLUME
CROSS : SENTRACHEM EARNINGS

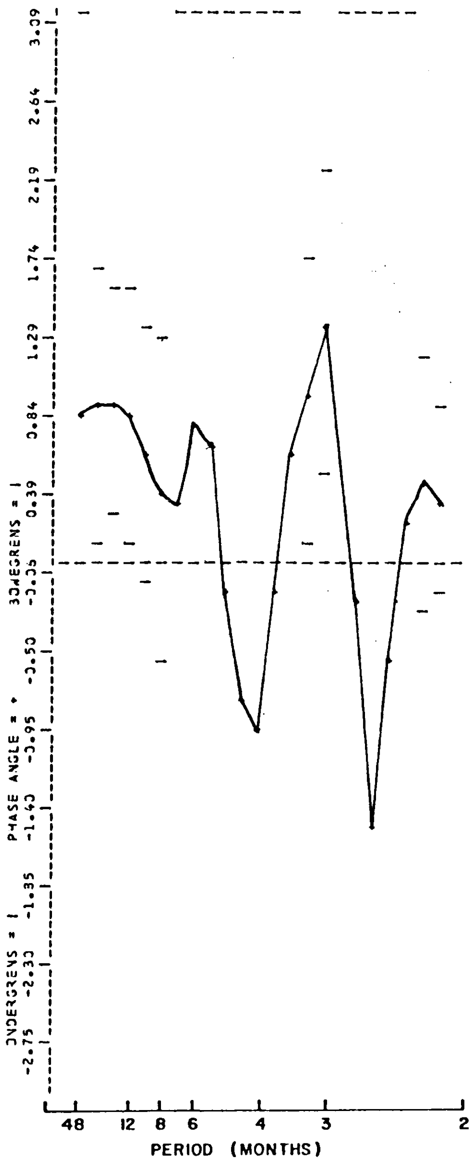


FIG 33 CROSS SPECTRUM PHASE

BASE : SENTRACHEM VOLUME
CROSS : SENTRACHEM EARNINGS

CHAPTER 8

CONCLUSION

This study has applied spectral methods to the variations in share prices in an attempt to add evidence to the efficient market and random walk debates.

A statement of the theory of spectral analysis has demonstrated its applicability to economic series such as share prices. The need to condition the data by differencing and logarithmic transformations has been researched in the literature and has been deemed necessary in the present study for all series, except earnings, which in any event represent a relative change between states.

The application of spectral methods to share prices, was first made by Granger and Morgenstern in 1963, but later work with the method has generally been confined to interest rates and the interrelationships of other economic indicators. This can in part be ascribed to the problems of interpreting certain of the relatively abstract concepts used. The single most important factor which makes spectral methods desireable, is the decomposition into frequency components that it provides.

The literature review on foreign stock exchanges has shown that the weight of evidence confirms the random walk theory as well as the weak and semi-strong forms of the efficient market hypotheses. At this time the available evidence for accepting the strong form of the latter is not conclusive. The tests which have principally been used are the serial correlation, cross correlation, runs, filter and other trading rules and tests of the performance of portfolio management.

A number of comparable tests have been performed on the share prices on the Johannesburg Stock Exchange and these have also demonstrated the efficiency of the market. Currently, the debate revolves around the proposition that a section of the market, characterised by shares with a low trading volume, is not efficient. Mainly the area of contention is the applicability and interpretation of the test and sampling methods.

The intention of this dissertation was to demonstrate the potential of spectral methods. The data which was used was chosen because of its availability rather than by a random selection process and thus certain biases have undoubtably crept in, such as will be caused by the selection of the figure for the Tuesday nearest the beginning of the month as the monthly data point. Notwithstanding this, a number of conclusions can be drawn. The analysis deals with harmonic relationships with periods greater than two months.

The comparison of the spectrum for the JSE industrial index with those of the Dow-Jones, Standard and Poor, UK Financial Times (Industrial) and the Eurosyn indeces shows that the JSE spectrum is flatter than all of the others, indicating that if anything, and contrary to expectations, the JSE follows a random walk more closely than any of the others. The spectra for the various economic indicators were not similar, indicating that the share price, as base series, was tested against a number of series with differing cyclic components.

The SA composite index was crossed with the overseas indeces, the local market indicators and with the individual share prices, earnings and volumes. The relationship between the SA composite index and Eurosyn index was found to be statistically significant and a maximum coherency of 0,84 was estimated. Since the estimated lag is on 0,6 months and bearing in mind the extent of the confidence bands, it is unlikely that this relationship could be used to generate excess profits. Of the South African market indicators tested, only the 90-day Bank Acceptances Rate showed significant coherency, although no consistent phase relationship was found.

The individual shares showed a high coherency with the composite index. This was to be expected since the shares chosen are among the most extensively traded shares on the market. These shares showed a phase shift of between 1,0 and 2,2 months, which suggests the use of the individual shares as indicators of the market index. The fact that the share price used was a monthly average and must be calculated post factor would reduce such a relationship to insignificance.

When the individual share prices were crossed with the other indicators, the only indicator which showed statistically significant coherency was the 90-day Bankers Acceptance Rate. There was, however, no consistent phase relationship.

The study reported here has several statistical weaknesses which could introduce biases. Further, the use of only 96 sample points to generate the spectra, has resulted in very wide confidence intervals and the conclusions are therefore somewhat tentative. The goal of demonstrating the use of spectral methods has, however, been achieved. Taken together the spectral analysis results presented here support the random walk hypothesis for shares on the Johannesburg Stock Exchange.

SUMMARY

In the past two decades theorists and practitioners alike have concerned themselves with the validity of the efficient market and random walk hypotheses. This study adds to the evidence which supports the random walk hypothesis for share prices on the Johannesburg Stock Exchange.

Spectral analysis performs a decomposition of a series (in this case share prices) into its component frequencies, resulting in a spectrum, the significance of which is that it is a presentation in the frequency domain of the contribution that any frequency makes to the overall fluctuation in the series. When generalised to the bivariate case, a number of spectral functions are produced which express the degree to which the two series are related and the timing or phase relationship between them. In particular, this study uses the coherency which expresses the linear correlation between the series at specific frequencies, the phase angle which measures the extent to which the series are in step at any frequency and the gain which can be regarded as the regression coefficient.

A number of definitions of the Random Walk Hypothesis have been found in the literature but the one preferred for this study was the mathematical one given by Granger and Morgenstern.

"If X_t is a discrete price series, the model suggested is that the first differences of the series appear to be purely random; in symbols

$$X_t - X_{t-1} = \mathcal{E}_t$$

where $\mathcal{E}_t$ has zero mean and is uncorrelated with $\mathcal{E}_{t-k}$ for all $k \neq 0$".

Although the empirical work was directed at the Random Walk Hypothesis, the literature review was extended to the Efficient Market Theory. Stated simply, this latter infers -

"A market in which prices "fully reflect" available information is called efficient".

The random walk model can be regarded as the "weak form" of the efficient market theory and implies that future prices cannot be determined from a knowledge of the historical prices. The "semi-strong" form includes all publically available information, not only prices, while the "strong form" removes the stricture of the information being "publically" available. The weight of evidence in the literature supports the efficient market theory in its weak and semi-strong forms. The evidence for the strong form is sparse and not yet conclusive.

For the empirical work of this study, the average monthly prices, volume traded and earnings for 11 shares on the JSE were obtained from the data bank of the Bureau for Financial Analysis. Comparison was made by spectral and cross spectral analysis, with the monthly values of the following indeces -

SA composite industrial from the Financial Mail
UK Financial Times Industrial
Dow Jones
Standard and Poor (425 industrial shares)
Eurosyn
Money and near-money
Physical volume of production (seasonally adjusted)
Manufacturing production (not seasonally adjusted)
Bank debits
90-day bankers acceptance rate
Consumer price index

In all 96 monthly observations between January 1970 and December 1977 were used. The data was conditioned by first differencing and logarithmic transformation. Apart from the univariate spectra, the coherency, phase and gain spectra were examined in an attempt to detect relationships which would suggest models in the time-domain. In the spectral analysis, 24 lags were used, i.e. N/4. In a spectral analysis 96 points can be regarded as less than desirable and

and consequently the confidence bands were very wide requiring rejection of many results on the grounds of lack of statistical significance.

The results show that if anything, the SA composite industrial index followed a random walk more closely than any of the overseas indeces. This is contrary to normally expressed opinion that smaller markets such as the JSE and the Australian Stock Exchange will exhibit less efficiency as the result of biases introduced by, for example, low trading volumes on certain shares.

The only statistically significant relationship which could be detected between the indeces was that between the SA composite index and the Eurosyn index. Here coherencies of up to 0,84 were observed. The phase spectrum suggests that the Eurosyn leads by 0,6 months at the point of maximum coherency. Although these results are statistically significant, it is unlikely that they could be used to generate excess profits.

The individual shares showed a high coherency with the composite index. This was to be expected since the shares chosen are among the most extensively traded share on the market. These shares showed a phase shift of between 1,0 and 2,2 months which suggests the use of the individual shares as indicators of the market index.

The fact that the share price used was a monthly average and must be calculated post factor would reduce such a relationship to insignificance.

When the individual share prices were crossed with the other indicators, the only indicator which showed statistically significant coherency was the 90-day bankers acceptance rate. There was, however, no consistent phase relationship.

The study reported here has several statistical weaknesses which could introduce biases. Further, the use of only 96 sample points to generate the spectra has resulted in very wide confidence intervals and the conclusions are therefore somewhat tentative. The goal of demonstrating the use of spectral methods has, however, been achieved. Taken together, the spectral analysis results presented here support the random walk hypothesis for shares on the Johannesburg Stock Exchange.

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